HISTORY OF THE MANUFACTURE OF EXPLOSIVES FOR THE GREAT WAR

SEE PAGES 21, 22, 23 AND 24 FOR DESCRIPTION OF TROJAN POWDER COMPANY'S WAR ACTIVITIES.

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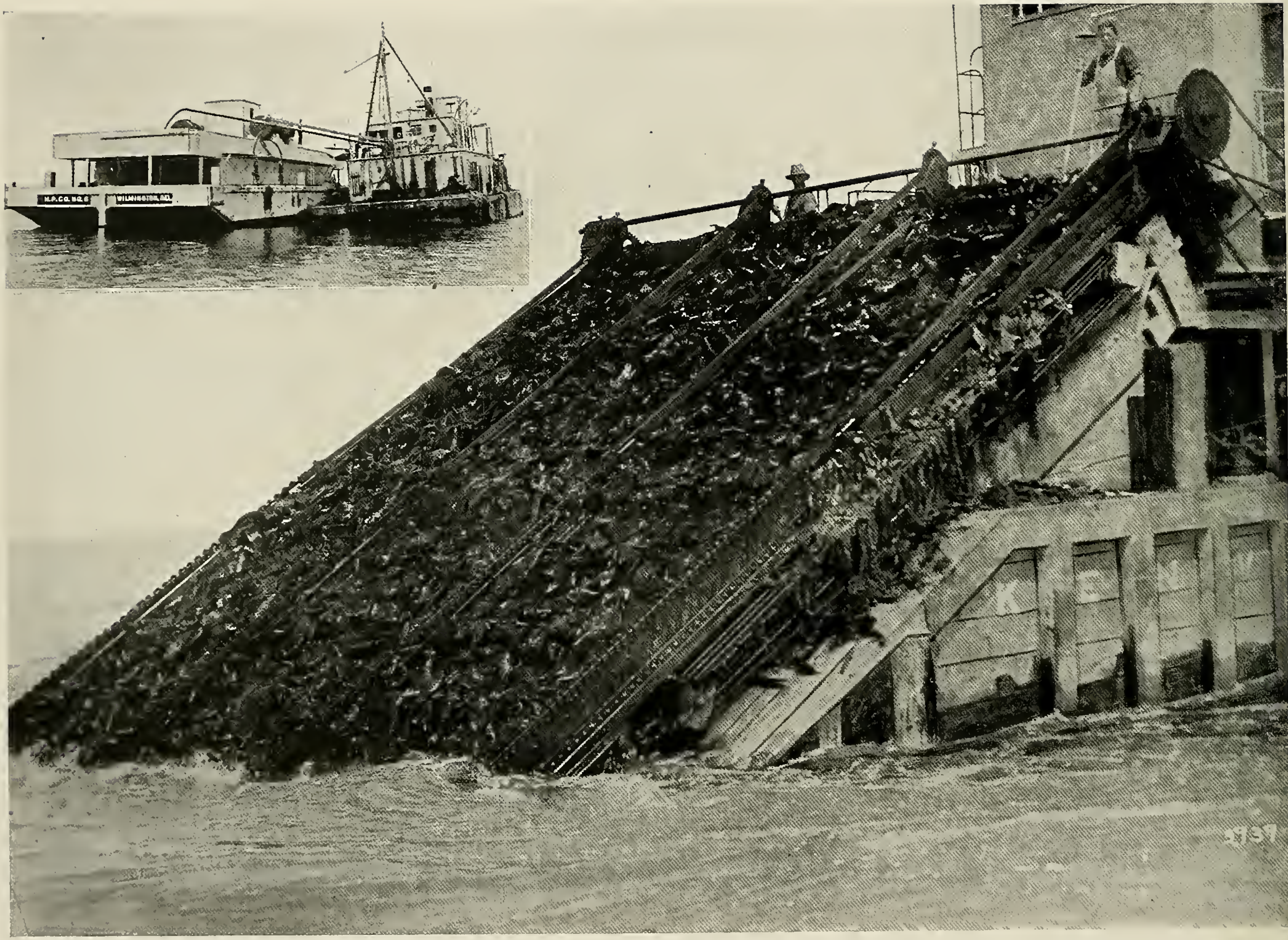
1917-1918



"Close up" view of Kelp Harvester at work off San Diego, California. The sea weed is shown here on its way (after cutting, or gathering) to the macerating process on deck. Upper left-hand view shows another barge alongside, pumping the macerated kelp into its own tanks. This barge carries the kelp to shore, where it is piped to the plant, half a mile inland (see page 33).

Major General C. C. Williams, U. S. A.
Chief of Ordnance,
Washington, D. C.

May 12, 1919.

Sir:

I have the honor to submit a history, in narrative and pictorial form, of the achievements of the Army Ordnance Department in the Philadelphia Ordnance District, in the manufacture of Explosives.

The principal headquarters of Explosives manufacture in the United States are, unquestionably, at Wilmington, Delaware, where are located the general offices of the greatest Explosives manufacturers, and it was thru the Philadelphia District Ordnance Office that most of the output under Government contracts has been supervised and cleared.

The history covers in some part, more than the Philadelphia District; this because of the fact that plants of the great manufacturers are scattered thru many districts, and it occurred that parts of many contracts were manufactured in different plants.

Aside from cold facts, as expressed in figures, this story is intended to point out the stupendous achievements of American Industry (rather than the achievement of any particular contractor); the difficulties, seemingly insurmountable, overcome; the colossal task of plant building; the extremely important achievements along the line of chemical research, all at a time when we were cut off from certain raw material supplies, obtained before the War from countries which later became our enemies.

For instance, as is shown on page 33 from a certain variety of giant sea-weed known as "Kelp," potash salt was obtained (an essential in the manufacture of black powder) which, upon chemical transformation, resulted in Nitrate of Potash, and it will be seen by the figures, that from the ocean itself came enough potash to make sufficient black powder to supply all our armies.

Not as a memento of the Great War is this submitted, but as an after-war review of scenes, the passing of which was so swift at a time when our thoughts were so centralized in our respective duties, as to preclude a possibility of keeping in close touch with them.

Even now, in reading this story of Explosives, we can but liken the scene to that of the wake of a departing ship — The Great War.

Respectfully,

WILLIAM B. WILLIAMS

General view of Dynamite Plant, Bacchus, Utah, where the Hercules Powder Company produced Nitrate of Ammonia (see page 32).

Introduction

THE purpose of this book is to show some of the remarkable achievements of American ingenuity and industry when put to the test. Ingenuity coupled with resourcefulness and backed up by industry.

Surely never before in the history of our country has such an opportunity presented itself to show the world, aye ourselves, our ability to rise to any emergency no matter how colossal in size, no matter how seemingly insurmountable!

Dry statistical data as to quantities of explosives produced has little meaning here. That the figures, were they mentioned, would prove astounding, no one can doubt. In this connection, however, the story of duPont is shown in a manner calculated to give the reader an idea as to the physical growth of plants under the emergency and in order to picture the "climb" of production, it was thought wise to go back to 1914 and follow the ever ascending scale of capacity while that company, like others, was supplying the demands of the Allies. Thus we arrive at the date April 6, 1917, when the United States went to the rescue, and it is interesting to note in figures the tremendous jump in production from that date. As with the duPonts, so with the other major explosives interests, capacities were strained to the utmost and the extremely low percentage of explosions and casualties in explosives plants in the United States (which at first thought seems marvelous) was but another proof of the efficiency of those directing the work, coupled with the word "carefulness," for it should be known that explosions are nearly always the result of someone's carelessness and not the fault of the explosive!

The Ammonium Nitrate Plant of the Atlas Powder Co. is shown at length, giving figures, as an example of plant construction under peculiar difficulties. Photographic views have been arranged with a view of showing at "close up" buildings which, while not necessarily standard, typify construction for like purposes, as a rule, throughout the country.

In contemplating the views of some of our major explosives plants as, for instance, Old Hickory, Hopewell and Carney's Point; in attaining a mental focus of the achievements of a little more than one year of time; in comparing America's work of a few months with that of Germany's thirty-eight years of cunningly designed and strategically applied preparedness, we can but declare that Alladin, with his wonderful lamp, was a mere tyro.

Obstacles arose and, almost as fast as they presented themselves, were overcome.

Such is the story of Army Ordnance. Credit for its achievements belongs, not to any one department nor any one industrial organization, but to the countless thousands of workers, from the official executives who planned, to the water-boys with their buckets and dippers, and it was "team-work," mental and physical team-work, *backed up by the scream of the eagle in his flight to the rescue of liberty,* that made these things possible.

THE AUTHOR.

It has been officially declared that there never was a time when the production of smokeless powder and high explosives did not only equal the American requirements, but in addition provided large quantities for France and England

History of the Manufacture of Explosives for the Great War

Showing the Achievements, from Year to Year, of the E. I. duPont de Nemours & Co.; Their Production in April. 1917, when the United States Entered the Conflict; and the "Climb" of Production from that Date Until the Signing of Armistice, November 11th, 1918

The story of the duPont Company's production of munitions during the European War naturally divides itself into three periods: first, pre-war; second, from the start of the war to April, 1917, when the United States joined the Allies; and third, from April, 1917, to the close of hostilities. These are treated in the order named.

The E. I. du Pont de Nemours and Company

First Period

IN 1914, after an existence of 112 years in the United States, duPont occupied the position of being the largest manufacturer of explosives in the world. Their main products, however, were commercial dynamites and black powder. As far as strictly military explosives were concerned, the United States government was, practically speaking, the Company's only customer. Its demands were small and consequently the Company's capacity and production were likewise.

While there was an efficient organization on which to build for expansion, conditions in this respect were less favorable than they had been. The duPont Company was dissolved by Court decree in 1912 into the Atlas, Hercules and duPont Companies. Operating, chemical and other officials were divided by the terms of dissolution and the re-organization of the personnel of the duPont Company had not yet been completed.

The outbreak of war found the explosives companies of England, Russia and France ill prepared to meet the requirements of their respective governments and the latter naturally turned to duPont to help make up the deficiency. The greatest demand was for *smokeless powder*. The Company's capacity for the manufacture of this commodity, together with other munitions, treated approximately in the order of their importance, is given below.

Smokeless Powder

Three plants—Carney's Point, Haskell and Parlin, all in New Jersey—with a combined theoretical capacity of 12,000,000 pounds of *cannon* and *rifle powder* per year.

Trinitrotoluol or Triton

Two plants. Repanuo, N. J., and Barksdale, Wis., capacity 660,000 pounds per month. Actual production approximately 1,000,000 pounds total since 1912, half of which was for use in *commercial dynamite*. The main capacity was for the manufacture of crude T. N. T. There was but little capacity for the manufacture of refined.

Black Powder

Plants at Wayne, N. J., Montchanin, Del., and elsewhere which, mainly employed in the manufacture of *sodium nitrate blasting*

powder, could readily be used for the production of *military black powder* for ignition and base charges.

There was ample capacity to meet all requirements except insofar as the manufacture of pellets for shrapnel was concerned. A suitable powder for pellets had not been developed and that Company had never attempted to manufacture pellets.

Tetryl

The duPont Company had no plant, and material had only been manufactured in an experimental way.

Fulminate of Mercury

Plant at Pompton Lakes, N. J., with capacity of 60,000 pounds per month. Actual production about 30,000 pounds per month.

Ammonium Nitrate

Plants at duPont, Wash., Louviers, Col., Barksdale, Wis., and Repauno, N. J. Capacity 1,350,000 pounds per month above commercial requirements.

As regards the items listed below the Company had no capacity or experience in production:

Trinitroxylol or T. N. X.
Ammonal.
Demolition Blocks T. N. T.
Ammonium Picrate.
Picric Acid.

Table No. 1 shows capacities as of July, 1914.

Table No. 1—Monthly Capacity duPont Explosives Plants

Material	Prior July, 1914	Material	Prior July, 1914
Smokeless Powder	1,000,000	Ammonium Nitrate	1,350,000
Trinitrotoluol—T. N. T.	660,000	Ammonium Picrate	0
Black Powder	550,000	Picric Acid	0
Tetryl	0	Ammonal	0
Fulminate of Mercury	60,000	T. N. T. Demolition Blocks	0
Trinitroxylol—T. N. X.	0		

Second Period

PRIOR to the war the duPont Company developed in connection with the United States Government a satisfactory nitrocellulose cannon powder, a nitrocellulose rifle powder and a nitroglycerin pistol powder. They had just completed the development of the progressive burning I. M. R. rifle powder when the war broke out. They had also developed a nitrocellulose pistol powder and sold a few thousand pounds per year to the sporting trade.

The British Government standardized on nitroglycerin rifle and cannon powder and when they opened negotiations in 1914 for the purchase of smokeless powder they wanted to specify nitroglycerin grades. The duPont Company insisted they would supply nothing but nitrocellulose powder to be manufactured with their current standards. The fact that the Company could offer immediate production caused England to accept the proposition. It is of interest and a source of satisfaction to know that England and Italy, who had previously been committed to nitroglycerin powder, continued to purchase the duPont nitrocellulose rifle and cannon powders to the end of the war and that England turned to duPont I. M. R. powders exclusively for small arms.

The duPonts signed a contract on October 12, 1914, to deliver 8,000,000 pounds of smokeless powder to France. Before April, 1917, they sold approximately 400,000,000 pounds of Smokeless Powder to the various allied governments, together with 27,000,000 pounds of guncotton. A plant was built at Hopewell, Va., for the manufacture of acid and the nitration of cotton. The Carney's Point, Haskell and Parlin Plants were enlarged and by April, 1917, the combined capacity amounted to 33,000,000 pounds per month.

There was a large demand for T. N. T. and between October, 1914, and April, 1917, about 50,000,000 pounds were sold to allied governments. The plant at Repauno was abandoned and that at Barks-

(Continued on page 10)


Hopewell, Virginia

THIS panoramic view shows the great guncotton plant of the duPont Company located at Hopewell, Va. It was built to supply the demands of the European War and from the early part of 1915, when operations were begun, until the armistice was signed, it produced 1,158,477,921 pounds of guncotton. It was looked upon as the greatest guncotton plant in the world. It employed at the peak 28.513 persons. Its community village had accommodations for 1,850 families. Its construction was a marvel of engineering skill and speed, the plant being completed in nineteen months!

On looking at this picture from left to right one sees to the left and prominently in the foreground "A" plant power house. To the left of the power house are the main office buildings and to the extreme left in the distance are the Norfolk & Western Railway station and the town of Hopewell. A short distance from the railway station is the main entrance to the plant. In the background, behind the stacks of the power house, are the cotton purification and dry house buildings of "A" plant.

At the right of the power house is the acid area. Immediately in the foreground to the right of the power house are nitrating houses and in the background and slightly to the right may be seen the stacks and buildings of nitric acid and acid recovery houses and sulphuric acid houses. About in the center of the picture and in the foreground the guncotton area begins. The large, low building in the foreground is a boiling tub house and to the right of it are beater, poacher, and blocking houses. To the right of the guncotton line is a three-story barn-like structure with a tank on the roof. This is the soda ash recovery plant and to the right of it is a group of buildings comprising the caustic soda plant and the acid water neutralization plant.

On the right of the picture are seen boiling tub houses with great quantities of steam coming from the stacks. Immediately in the rear of these houses is the stack of "C" plant power house and the large building in the background to the left of the power house stack is a raw sulphur storage house. To the left of this and also in the far background is the "C" sulphuric acid plant. At the extreme right of the picture and in the background are seen buildings of the "B" plant guncotton lines.

The river seen in the background to the extreme left of the picture is the Appomatox while farther to the right and in the background is the James River. On this latter stream were the wharves of the Hopewell plant and most of the guncotton was shipped from there.

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Parlin, New Jersey

THIS is a panoramic view of the smokeless powder plant of the duPont Company located at Parlin, N. J. It was one of the important duPont plants engaged in supplying munitions for the Allies and the United States Government. Previous to its great expansion to supply the needs of the Allies just after the outbreak of the European War, this plant had a capacity of approximately 7,500 pounds of cannon powder per day. Its output was built up from this figure to that of 375,000 pounds of military smokeless powder per day, and 30,000 pounds of guncotton per day. The remainder of the guncotton needed for its smokeless powder was brought from Hopewell, Va.

At the peak this plant employed 4,900 persons. It had housing accommodations for 1,100 bachelors, 400 single women, and dwelling houses for seventy families.

This picture shows among other things, ether houses, power plants, solvent recoveries and blending towers.

On the extreme left are ether houses of what was known as Plant No. 2; the three stacks towards the left of the picture are those of the new power house. Further to the right are shown the three stacks of the old power house. Immediately in front of these stacks are located the buildings of the guncotton line and between the old power plant and the new power plant are some of the buildings of the chemical plant.

To the right of the old power house the buildings in the center background are mechanical shops, and farther in the background are dwelling houses located outside the plant. A little to the right of the center of the picture is seen a large water tank used as part of the fire protection and immediately to the right of it are ether houses of plant No. 1. In the foreground to the right of the picture are seen two mixing houses and immediately to the right of them are five finishing press houses. Farther to the right is seen a line of solvent recoveries. In the rear of the solvent recoveries, prominently located on a slight hill, is a new type water dryer. The buildings immediately in front of this are old type water dryers.

dale enlarged so that in April, 1917, it had a capacity of 4,000,000 pounds per month.

duPont furnished 2,000,000 pounds of black powder for bursting charge in shrapnel and 700,000 pounds of fuse powder for time trains. It was reported by the British Government that results obtained by their inspectors with duPont fuse powder, indicated it to be superior to all others.

There was also a large demand for black powder pellets for time fuse and shrapnel. Experimental work was started late in 1914 as a result of which a suitable powder was developed and the manufacture of pellets developed. One hundred and thirty million pellets of possibly eighteen different sizes and styles were sold prior to our entrance into the war.

A plant was constructed at Deepwater Point, N. J., for the production of Tetryl. By April, 1917, this plant was able to produce 60,000 pounds per month.

The Pompton Lakes Fulminate of Mercury Plant proved ample to meet all needs.

The manufacture of Picric Acid and Ammonium Picrate was started at Deepwater Point and plants built with capacity to make 125,000 pounds per month of the former and 250,000 pounds per month of the latter commodity.

Table No. 2 shows capacities as of April, 1917.

TABLE NO. 2—MONTHLY CAPACITY DUPONT EXPLOSIVES PLANTS

Material	Prior July, 1914	April, 1917
Smokeless Powder	1,000,000	33,000,000
Trinitrotoluol—T. N. T.	660,000	4,000,000
Black Powder	550,000	550,000
Tetryl	0	60,000
Fulminate of Mercury	60,000	60,000
Trinitroxylol—T. N. X.	0	0
Ammonium Nitrate	1,350,000	1,350,000
Ammonium Picrate	0	250,000
Picric Acid	0	125,000
Ammonal	0	0
T. N. T. Demolition Blocks	0	25,000

Third Period

WHILE the Allies' demands had been enormous, they were not nearly as large as the requirements of our Government when she entered the war in April, 1917. duPont was, however, able to offer sufficient capacity to meet the entire first program for cannon and small arms powder, but it later became evident this would not be sufficient and that there was not enough smokeless powder capacity in the entire country to meet the enlarged program.

The Government decided to build two plants, each with a capacity of 500,000 pounds per day and duPont was asked to assist them in selecting the sites and also to design the plants. Sites were selected at Charleston, W. Va., and Nashville, Tenn., and the plant at the latter place was built by the duPont Engineering Company. The speed at which this last plant was erected established a record for surpassing anything previously done—ground was broken on March 8th, and in June operation of an acid unit was started. Since that time 30,000,000 pounds of smokeless powder have been produced at Old Hickory (near Nashville).

At the close of the war the company's capacity for the manufacture of smokeless powder amounted to 1,700,000 pounds per day and was being rapidly increased by additions to the Old Hickory plant which would give the latter a capacity of 900,000 pounds per day. Incidentally all powder manufactured was packed in boxes built in duPont shops to a large extent from wood obtained from the Company's mills and land.

In the latter part of 1917 an extension was built to the Barksdale Plant so as to run its capacity for the manufacture of T. N. T. up to 6,000,000 pounds per month. In spite of this increase the production of T. N. T. was still inadequate and the Company was asked in the middle of 1918 to contract and operate a duplicate plant at Racine, Wis. Construction work had started when the Armistice came.

The capacity for the manufacture of Tetryl was increased so that by the end of the war, production amounted to 150,000 pounds per month.

There was a demand from the Engineer Corps for a special class of explosives for engineering and sapping work and the Company started in 1916 at Carney's Point to make compressed rectangular and cylindrical blocks of Triton approximately one-half pound in weight. The work was later transferred to Barksdale. Production amounted to 25,000 pounds per month. Blocks so made did not stand up as well as desired in transportation and handling and in July, 1917, the Company was asked to consider the copper plating of such blocks. The Engineer Department had done some experimental work along these lines and with the help of their experience the duPont Company installed a copper plating equipment and started production late in 1917. Production reached 65,000 pounds per month by the middle of 1918. This met their program.

It was found that the ordinary type of detonator was not strong enough to properly explode the blocks so the duPont Company designed and manufactured at their Detonator Plant, Pompton Lakes, New Jersey, a detonator considerably stronger than any previously made commercially, which gave complete satisfaction and it has been adopted as the standard.

For sapping work they wanted an explosive of the Ammonal type. The Chemical Department developed such an explosive, known as duPont Ammonal, and in field tests at Camp Dix and elsewhere, it proved the equal, if not the superior, of T. N. T. as a sapping explosive.

The duPonts supplied the Government with their total requirements. 1,300,000 pounds, between May, 1918, and the close of the war. The English had used compressed guncotton as a primer. The duPonts suggested compressed Triton Blocks as a better and safer booster and this plan was adopted.

The Engineers required an explosive for quarry operations in France. A 40 per cent low freezing gelatin was recommended; over 1,000,000 pounds of this explosive were manufactured.

The duPonts also held contracts covering an immense loading program and they loaded the majority of the aeroplane drop bombs loaded in this country. Approximately 40,000 were turned out at Repauno. These were loaded with Lyconite, an explosive developed by duPont chemists at their Eastern Laboratory, Gibbstown, N. J., especially for drop bombs; 1,200,000 pounds of Lyconite were used.

Early in June, 1918, German submarines appeared off the Eastern Coast and sank a number of ships. Ordnance Department officials appealed to duPonts, by telephone, to load 300 bombs. A special messenger brought the necessary primers from New Haven, Conn., and by everyone pitching in and working day and night they managed to ship half of the quantity of bombs by truck in twenty-four hours and the remainder in forty-eight hours!

For the Livens Projector, a nitrocellulose container for the propellant charge was developed which was given the name of nitrotite. This was adopted by the Ordnance Department to replace the English arrangement of cotton bags separated by a tin segmental contrivance. These containers were being loaded at the rate of 1,000 per day on an order for 137,000. Just before the War ended the Company accepted an additional order for 900,000 to be supplied by June, 1919, and a new plant at Brandywine, Del., with a capacity of from 4,000 to 6,000 charges per day had almost been completed.

Nitrotite was developed mainly as a substitute for silk propellant containers used in unfixed ammunition and 50,000 were furnished for the 155 m.m. gun. The English had been experimenting with a somewhat similar material, but without success, so Nitrotite was distinctly an American creation which was not only the equal of silk in important respects, but superior in many.

TABLE No. 3—MONTHLY CAPACITY DUPONT EXPLOSIVES PLANTS

	Prior July, 1914	April, 1917	Armistice Month Nov., 1918
Smokeless Powder	1,000,000	33,000,000	52,000,000
Trinitrotoluol—T. N. T.	660,000	4,000,000	6,000,000
Black Powder*	550,000	550,000	550,000
Tetryl	0	60,000	150,000
Fulminate of Mercury	60,000	60,000	60,000
Trinitroxulol—T. N. X.	0	0	2,500,000
Ammonium Nitrate*	1,350,000	1,350,000	1,350,000
Ammonium Picrate	0	250,000	250,000
Picric Acid	0	125,000	125,000
Ammonal**	0	0	700,000
T. N. T. Demolition Blocks	0	25,000	65,000

*Above commercial requirements.
**Had facilities to increase if necessary.

The foregoing tells the main story of quantity production, but this Company handled many projects of a special or experimental nature which are not covered.

At their Eastern Laboratory, Gibbstown, N. J., their chemists, in co-operation with Ordnance Department officers, carried on experimental work to determine proper bursting, booster and detonating charges for various shells and bombs, and loading specifications were ordinarily drawn as a result of this work.

Lyconite, an explosive for bombs, and Grenite, an explosive for grenades, were developed by the Chemical Department and sold to the United States.

The manufacture of diphenylamine. the necessary stabilizing agent for smokeless powder, was developed. Previous to the war, this material was not manufactured in this country and its successful manufacture constitutes one of the greatest single achievements in this line. during the war.

Pistol Powder, No. 3, a nitrocellulose powder, was adopted by the Ordnance Department, and was manufactured at the rate of 2,000 pounds per day, which met the requirements.

The duPont No. 3 blasting machine was decided upon as the standard for the engineers and 300 were manufactured in two months' time on a rush order. This was a large order for this class of material.

On request from the Engineers, the duPonts assisted in the design of demolition outfits, to be carried by the men in the field, and assembled 87,000 at their Pompton Lakes Plant.

Other divisions of that company supplied large quantities of their products either directly or indirectly to the Government, as, for instance, Pyralin for gas-mask eye-pieces and battery jars, coated fabrics for clothing, dugout curtains, etc., as a protection against poisonous gases and fire, various special chemicals and acids, large quantities of paint for camouflage of ships, etc., and dopes for aeroplanes.

With but one or two exceptions, production proceeded according to schedule and in many instances was better than commitments. Considering the volume of business, the amount of new construction necessary, the labor turnover. etc., the results obtained were truly remarkable.

We have all heard much of the rapid strides made by various American industries during the war, notably shipbuilding and steel manufacture, with its associated branches, but there has been little said or written about the *explosives industry*. The average citizen does not realize that the explosives companies were no more prepared at the start of this war to meet the demands which they later did meet than the shipbuilders were to build ships and not as well prepared perhaps as the steel manufacturers to take care of the increased demands for steel plates, rails, locomotives, shells, etc. The way in which the duPont organization was enlarged, new plants built, methods of manufacture improved and production increased, constitutes one of the greatest achievements in American industrial history. Incidentally (as an outgrowth of the war) it might be added that E. I. duPont de Nemours & Company also found time to put their peace-time activities on a more substantial basis and to develop the manufacture of dye-stuffs to such an extent as to make this country largely independent of Germany.

"Old Hickory"

The Greatest Smokeless Powder Plant in the World Near Nashville, Tennessee

THE stupendous achievement of the duPont Engineering Co. an offshot of the great explosives firm of E. I. DuPont de Nemours & Co., in creating this plant for the Government during the first months of the second year of the great war, has been acknowledged by the Chief of Ordnance himself in a letter from which we quote herewith as follows:

"Since the signing of the armistice and with the cessation of munition production there has been brought to my attention a review of your work on the Old Hickory Smokeless Powder Plant at Nashville, Tenn.

"To have built up and put into operation the first units of such a plant in less than five months from the date of breaking ground, under the stressful conditions existing, involving, as it did, the construction not only of the major plant, but of a number of subprocess plants, each of which in itself might be regarded as an undertaking of no little magnitude, must always be regarded as a remarkable achievement.

"The fact that this initiation of operation was accomplished some two months prior to contract promises and that production has been since maintained at all times in excess of contract requirements, still further embellishes the very perfect construction record.

"The history of what you have done at Nashville is paralleled by the very satisfactory and uniform fulfillment of your expectations on practically all other work you have undertaken for the Government. All of this on materials that were most vital to the successful issue of the war.

"It is, therefore, a distinct pleasure to express to you the very sincere appreciation of the Ordnance Department for the highly efficient and fruitful part your Company has played in the development of the munition supply."

As is indicated in General Williams' letter, operations in the manufacture of Smokeless Powder started five months after breaking ground. This means that instead of delays (which naturally could be looked for under such conditions as prevailed throughout the country) finished powder was turned out for our armies *ahead of scheduled time.* Thirty millions of pounds of smokeless powder had been produced at Old Hickory up to the time the whistles were blowing to quit on November 11th, 1918.

Construction proceeded from the start in leaps and bounds. Again and again top notches were cut in speed records. As we proceed in the review of Old Hickory, and as we consider such factors as time, labor and materials, the term "magic" seems more and more appropriate.

The fairy wand in this case (metaphorically speaking) being the Eagle, who, from the heights saw the menace. Spreading the alarm from horizon to horizon, the forces of a nation responded one hundred per cent. All the ingenuity; all the energy; all the resources; all the determination. All—one hundred per cent All—responded, and when the Eagle successfully rid his domain, aye, all humanity, let us hope, of the menace which threatened, back to his eyrie he flew. His duty accomplished. We have the secret. Old Hickory was one of the very many stupendous developments.

Look upon the panorama of the workshops of the victors. Behold, in full relief, marvels of construction; walk about—not among ruins, but a vast completed work. "What," you say, "Walk over a reservation the area of which is 4,706 acres, and go in and out of more than a thousand buildings?" We answer: "Why not? The roads are ample; more than seven miles of concrete and four miles of macadam; thirty-three miles of board-walks!" You say that such a trip is out of the question. Well, then, stand with us up here in a tower 160 feet high and look down upon the scene. Over here, (page 16) at top, are the Nitric Acid and Sulphuric Acid Plants. This plant had started on the production of sulphuric acid nine weeks after ground was broken for the acid lines. Terra cotta and brick constituted the type of buildings in the acid manufacturing zone. In such buildings colossal vats and tanks were installed. Nitrate of soda and sulphur were stored in their respective store-houses erected with a view of being conveniently near the units which would require these materials. Millions upon millions of pounds of nitrate of soda and of sulphur were kept on hand in these buildings. On the same page at bottom is the gun cotton belt. Millions of pounds of cotton were stored in immense warehouses. These warehouses were sheathed with corrugated iron.

On page 15 is shown at top the Smokeless Powder Lines. Ground was broken March 4th and on July 2nd powder was manufactured and yet another world's record for speed established. This was 116 days after breaking ground. At the bottom of same page is shown the village. The magic city. To house and feed and care for the 30,000 persons whose homes must needs be near the plant was a gigantic problem in itself.

But another rub of the "Wonderful Lamp" and Alladin-like, where but a few months before was heard the lowing of the kine; where quietude was broken only by the whiz of the threshing machine, or the voice of the farmer speaking to his plow horses, there grew, magic-like, a city.

A city with its hospitals, its police and fire departments, its hotels, churches, schools and amusement places. A modern city, if you please, with improved sewage system — miles of it — incinerating plants and a really wonderful reservoir and filter plant. There was a Mexican village of forty-one buildings where 3,000 Mexicans were quartered.

Schools for white and colored children were erected. and again speed records scored when an immense school house was completed and ready for use in ten days. These schools were 250 feet by 350 feet.

Construction of the village took the sky-rocket phase when a six-room bungalow was completed in nine hours, including the plumbing, screening and all other details. In another case a two-story block apartment building containing six houses. began at 7.30 in the morning, when excavation was started for the foundations, and was ready for occupancy twenty-nine and a half hours later. Just think of it! A block of six houses in twenty-nine and a half hours! And this with the fact that during this time the work was hampered by reason of men who were at work on it being required to leave for a time, in squads of ten and fifteen, to go to headquarters and register under the Selective Service Act.

The "Village" at Old Hickory contained all the phases of a modern city. There were nearly fifty miles of terra cotta sewers, thirty-three miles of board-walks, forty-four miles of water lines, 3,867 buildings requiring in all 65,000,000 board feet of lumber, or enough to lay a plank along the borders and seacoasts of the United States, with enough lumber left over to erect large watch-towers at each of the four corners. As many as 1,125,945 meals were served in one month.

A bridge was erected across the Cumberland River, made necessary by the fact that trains carrying thousands of operatives who lived at Nashville and other places, discharged their passengers on the opposite side of the river from the plant.

The bridge is a single steel span suspension, 540 feet span with trestle approaches carrying 1,260 feet or 1,800 feet in all. The floor of the bridge is ninety-one feet above the actual water level. Not one accident to any of the construction workers was reported.

Thus, when we arrive at the memorable eleventh hour, of the eleventh day, of the eleventh month, we behold the progress of the human race, for surely it was required to deliver the best it had and one of the developments of the great war was, without doubt, *the development of the human race.*

Old Hickory, Nashville, Tennessee

THIS is a panoramic view of many of the most striking features of the Old Hickory powder plant, constructed for the United States Government by the duPont Company, near Nashville, Tennessee. The plans, experience and skill necessary for the construction of this, the largest and best smokeless powder plant in the world, were supplied by the duPont Company to the United States Government for a consideration of one dollar.

The plant was built to have a capacity of 900,000 pounds of finished smokeless powder per day. It is complete in itself. The total area of the reservation, including the plant and the village for the employees adjoining, is 4,706 acres. All speed records were broken in constructing the plant. *Powder was produced in five months after beginning the work*, instead of the eight as specified in the contract. At the signing of the armistice, manufacture of powder was 13,000,000 pounds ahead of contract requirements and construction work 96 days ahead of schedule time. This panoramic view gives an idea of the enormity of the work.

To the far right of the picture is the main power house, sedimentation basins and filter buildings, with the finished stage powder area in the distance. Towards the left and in the foreground are batteries of solvent recovery buildings. In the rear center are the air dry buildings. To the right of the solvent recovery buildings lies the first stage powder lay-out, covering the press buildings, ether houses and alcohol units. To the center of the picture in the foreground may be seen various buildings of the cotton purification area. Stacks of burner houses of the sulphuric acid line are seen in the distance in the center.

Old Hickory, Nashville, Tennessee

IN this panorama of Old Hickory smokeless powder plant, constructed by the duPont Company for the U. S. Government, near Nashville, Tenn., are shown the central power house, acid mixing and weigh, nitrating and cotton purification houses, boiling tub houses, pulping lines and part of the first stage powder area. The enormous power plant shown in the center of the picture is in many respects the greatest in the world. It was built to generate at full production of powder, 60,000,000 pounds of steam every twenty-four hours! If used to generate electricity this amount would exceed that necessary to supply the city of New York. Its coal storage has a capacity of 100,000 pounds. There are sixty-eight boilers, each with a rated capacity of 823 H. P. Its filter plant consists of eight units of twelve filter tubs each, with a total capacity of 65,000,000 gallons every twenty-four hours. Electricity is generated in seven steam turbo-generators, with a total capacity of 17,500 K. W. The refrigerating plant is the largest in the world. It has a total capacity of 3,250 tons of refrigerating effect every twenty-four hours. There are thirteen ammonia compressors, driven by specially constructed engines.

Near the power house is shown the shop area, with the water dry district of the powder area in the background.

The large buildings shown to the left of the picture are the cotton purification houses, with the stacks of the sulphuric acid and nitric acid houses shown in the background. The main concrete road to the lower plant is shown passing through this area. In the left of the picture near the center are boiling tub and poacher houses of the cotton purification area and the tall narrow buildings in the middle distance are blending towers. The continuous dryers of the finished powder area form the background.

To the right of the power house is the first stage powder area with alcohol rectifying units in the foreground. The poacher units of the gun cotton purification area can also be seen in the immediate foreground.

Old Hickory, Nashville, Tennessee

THIS is another interesting view of Old Hickory, the largest powder plant in the world, constructed near Nashville, Tenn., for the United States Government, by the duPont Company In this picture is shown much of the area devoted to the manufacture of guncotton. The capacity of the plant for manufacturing guncotton is 1,000,000 pounds per day. It has a total crude fibre storage capacity of 42,000,000 pounds. There are complete plants for the making of sulphuric and nitric acids. The sulphuric acid plant has a capacity of 2,400,000 pounds per day. A total of 1,112 buildings and 32.12 miles of tram tracks were constructed on the plant. Before the construction could be started seven miles of railroad had to be built and this was completed in 29 days.

This panorama shows the nitric acid plant, blending towers, a cotton purification building under construction, a completed purification building and other structures of the guncotton area.

To the extreme left in the foreground is a retort house of the nitric acid unit. In the background towards the left are shown blending towers and continuous dryers located in the finished powder area. At the left center in the background can be seen the stacks of the main power house and in the foreground stands the steel work of an uncompleted purification unit; slightly more to the right are completed purification units.

In the foreground of the center are the pre-heater houses of the sulphuric acid area. (These may be recognized by their black steel stacks). Towards the right may be seen the roof of the sulphur burners of the sulphuric acid area. At the extreme right may be seen the main office with pay booths to the left. The Mexican camp is in the background. A partially completed nitric acid retort house with acid storage tanks completes the extreme right of the picture.

Old Hickory, Nashville, Tennessee

THIS panorama shows the community village, large enough to be called a city, adjoining the Old Hickory smokeless powder plant, near Nashville, Tenn. Both the village and the plant were constructed by the duPont Company for the United States Government.

In this village were constructed accommodations for 30,000 persons. Besides the dwellings for families there were mess halls, camps and barracks for bachelors, dormitories, comfortably fitted up, for women employees, a great commissary store at which food was sold at cost, and a central heating plant for the camps and barracks.

The village had all the facilities of the most up-to-date city. There were recreational and social centers, a staff of welfare workers, and the most thorough sanitary and police protection.

Some of the dwellings were of temporary construction; some were splendidly built permanent houses; all were comfortable and equipped with the most modern sanitary facilities. There were ample school facilities for the children and opportunities for evening study for adults. In the village were two hotels, each with accommodations for 200 persons. Modern concrete roads ran through every part of the development.

To the extreme left of this panorama can be seen one-story six-room bungalows. To the right of these bungalows are one-story apartment houses and still further to the right are numbers of two-story apartment houses. To the left of the center are seen the main stores and receiving rooms for the village construction supplies. In the center to the right of the concrete road and in the background may be seen the houses of the permanent village. In the extreme background is the outline of the duPont hotel and the dormitories for women.

At the right of the picture in the foreground, along the concrete road, may be seen additional six-room bungalows, with the village Y. M. C. A. in the center of the foreground.

Rubberoid six-room bungalows form the background at the right, and in the background at the right may be seen also the iron stack of one of the large village schools.

Carney's Point, New Jersey

WHEN the United States entered the war against the Central Powers in the spring of 1917, the smokeless powder plant of the duPont Company, at Carney's Point, N. J., was perhaps the most famous establishment of its kind in the world. It had probably done more than any other single powder plant to help win the war for the Allies. Continually in operation, on an enlarged scale, since the early part of 1915, its output then had reached a quantity never before achieved in this country by any works devoted to smokeless powder making. Its capacity before the war was approximately 12,000 pounds per day. From this point it was built up to an output of 900,000 pounds per day. In order to meet the demands of the Allies, and also the demands of the United States after we entered the war, the plant was run day and night, rush orders and overtime being the rule. From the early part of 1915 until the signing of the armistice, it furnished approximately 758,000,000 pounds of smokeless powder.

The comparatively small capacity of the Carney's Point plant when the European demands began necessitated immediate construction on a large scale. Roads were laid out, vast quantities of material assembled, new power houses built and construction carried on so rapidly that finished powder was delivered ahead of time. At the peak, with both the engineering and operating forces counted, this plant employed approximately 25,000 persons. When it was in operation the power houses of the factories at full capacity required the continuous development of 25,000 boiler horse power; the pumping stations had a capacity of 41,000 gallons per day; the average K. W. of electricity developed was 1700; the filtration plants filtered and purified 9,000,000 gallons of water per day; and the refrigerating apparatus had a capacity of 3,000,000 pounds of ice per day. The total yearly coal consumption amounted to 377,000 tons.

Prior to the war the duPont Company had made comparatively little powder for foreign nations. The sudden call of the Allied governments required the fitting of the duPont form of powder, then almost unknown abroad, to guns designed to use other ammunition. This necessitated development by this company of forty different powders for as many guns. These powders function under exacting specifications—though some of them average 42,000 pieces to the pound, each of these pieces is a perfectly formed cylinder with one or seven longitudinal perforations whose important dimensions require an accuracy of not more than 1/1000-inch variation from the mean.

In addition to the foreign powder, the United States government needed, for Army and Navy use, ninety different powders, all produced under strict specifications. Many changes in the ballistic requirements of the guns made it necessary to re-establish the characteristics of the powder, a change that was equivalent to the fitting of entirely new guns.

The production of this great amount of work was carried on at the various duPont plants and Carneys Point had its full share. It will be appreciated that the production of military propellant powders is an exact science and that the wonderful achievement in enormous production brought about is increased in value when the minute care that is necessary to produce accurate results is considered. The measure of success attained lies in the fact that all specifications were met while not a single lot of powder failed of final acceptance and no powder was returned as unsatisfactory.

Coincident with the expansion of the works, steps were taken to provide housing accommodations for employees. Large camps were established, capable of housing thousands of men. These were composed of bunk houses, the majority of them being of the type that sheltered four men each. All were steam heated from a central point. Bath houses were placed at convenient places, streets were laid out, a system of lights installed and large mess halls were established where food was sold at cost. The conditions in the camps were always healthful and no epidemics took place, with the exception of the Spanish influenza, of course, and this swept through the entire country, sparing no community.

The company also began at once the establishment of a comfortable village for families. Large numbers of temporary houses were constructed, each with its plot of ground. Streets were laid out, a street cleaning system installed and every convenience of a large city put at the disposal of the employees. There was a number of types of these temporary houses, some of them being six-room bungalows, other six-room apartment houses, while still others were four-room dwellings. All of them were equipped with electric lights and baths. All were comfortable and sanitary.

In the village was also a number of permanent houses. These were larger than the temporary dwellings, were substantially built, with all modern conveniences and with ample lawn space.

After the United States entered the war several hundred women were employed at the powder works at Carney's Point and special club houses were built for them. These houses had large reception rooms and were comfortably furnished. Each club house also had all facilities for ironing, sewing, and washing and these were placed at the disposal of the women without charge. Matrons and welfare workers did everything possible to help create the best kind of social and recreational life for them.

Besides the thorough sanitary and upkeep work in the village great attention was given to welfare service. There were visiting nurses who helped out with the sick. Physicians were available. Community houses were established, club houses were opened and playgrounds laid out and operated. These playgrounds for children were in charge of trained play supervisors and were highly successful. There were ample school facilities and the attendance was very gratifying. The Young Men's Christian and the Young Women's Christian Association had headquarters in the village. The boys and girls were organized, schools for adults were established, and every effort made to interest the workers in their own betterment.

In all, the village at Carney's Point had a population of about 10,000 men, women and children. Everything possible was done to assist them in beautifying their homes and prizes were offered to those who had the best gardens. Land was also placed at the disposal of families, for a nominal sum, on which to plant vegetables.

In effect the so-called village was a small city and it was run by a corps of competent quartermasters. During the time when the powder plant was working night and day supplying the demands of the Allies and the United States, no serious accident or catastrophe marred the village life. The rental of the houses was extremely low. While rentals were soaring in the munitions districts, the employees at the Carney's Point village were able to rent the smaller houses at $6.50 per month, the six rooms and bath bungalow at $8.50 per month, and the substantial, modern houses in the permanent section up to $25 a month.

These facts are incorporated in this story for the purpose of showing the very commendable spirit of the War Contractor (giving this as an example) in doing absolutely everything possible to make the environment of his employees comfortable, cheerful and wholesome, adding wonderfully to the efficiency of the employee, and at little or no profit to the contractor. Indeed we know that in many instances it was at a loss rather than a gain that such surroundings were provided.

Hopewell, Virginia

THIS is another panoramic view of part of the guncotton plant of the duPont Company, located at Hopewell, Va. Some idea of the enormity of the work required to construct and operate this great establishment can be gathered from a study of this scene. To construct the plant there were used approximately 175,000,000 board feet of lumber, approximately 13,000,000 bricks, 210,000 barrels of cement, 4,500,000 square feet of composition roofing material, 6,500,000 square feet of flat and corrugated sheet iron and 600 miles of wrought iron and steel pipe! There were 65 miles of cast iron pipe, 45 miles of terra cotta and 13½ miles of wood stave pipe employed. Broad gauge tracks totalling 23 miles and narrow gauge tram lines totalling 32 miles were laid down within the plant.

The rapid construction and efficient management of the Hopewell plant constituted one of the essential factors in the great work of the duPont Company during the European War, when all ammunition was supplied on time and not one pound of powder was ever finally rejected.

This panoramic view shows portions of the power, acid, cotton purification and guncotton areas. To the extreme left are the stacks of the nitric acid plants and the acid recovery plants. The large building in the immediate foreground at the extreme left is one of the acid mix and weigh houses and immediately adjoining it on the right are three acid storage tanks. The large building immediately adjoining these tanks on the right and in the foreground is a boiling tub house and the buildings in the background in the rear of it are beater, poacher and blocking houses. In the center are the stacks of "B" plant power house and the large structure in the background to the left is a cotton purification house. The small buildings in the foreground to the left of the power house were used as headquarters for minor executives. Looking to the right from the power house are four large buildings. These are cotton purification houses and the low structures near them are cotton dry houses.

Carney's Point, New Jersey

THIS is a panoramic picture of part of what is perhaps the most famous smokeless powder plant in the world. It is located at Carney's Point, N. J., and is the property of the duPont Company. It was a vital factor in the great European War, furnishing a total of 758,000,000 pounds of smokeless powder to the Allies. At the peak it employed approximately 25,000 persons. It covers 3,300 acres and consists of nearly 1,000 buildings. In connection with the making of smokeless powder during the European War approximately 600,000,000 pounds of ether were manufactured on this plant! If properly administered this amount would etherize the population of the world four times! The total length of the strings of powder manufactured at Carney's Point would reach from the earth to the moon and back 173 times, a distance of approximately 83,000,000 miles! On the plant were 143 shipping houses with a storage capacity of approximately 70,000,000 pounds. Adjoining the plant was a community village with a population of 10,000 persons, with social centers, Y. M. C. A. and Y. W. C. A. houses, hotels for bachelors, dormitories for women workers, playgrounds for children and a corps of welfare workers. The great acreage covered by this plant can be fully realized from this panorama.

At the extreme left in the foreground may be seen the finished powder buildings with the stack of No. 1 plant power-house in the background. Towards the left center are the water dryers of the finished powder area, with the stacks of the power house of Plant No. 2 in the immediate background. At the right near the center, in the immediate foreground, are solvent recovery sections with the stacks of the power house of Plant No. 3 in the background. Towards the right of the picture in the foreground may be seen a solvent recovery area, with press line and the stacks of the Deepwater Point picric acid plant in the background.

E. I. duPont de Nemours & Company

The Power Houses of their factories at full capacity required the continuous development of 200,000 boiler horse-power.

The pumping stations have a capacity of 305,000,000 gallons per day, exceeding the combined daily water consumption of the cities of Philadelphia and Boston.

The filtration plants filter and purify 175,000,000 gallons of water per day, to a degree satisfactory for domestic as well as for manufacturing use.

The refrigeration apparatus has a capacity of 9,350,000 pounds of ice per day, equal to the consumption of the city of Chicago.

Railroad classification yards, capable of handling 1,600 cars at one time, have been laid out and are in operation.

One hundred miles of standard railroad and 208 miles of narrow gauge railroad have been constructed.

The enclosing of the plants required over 150 miles of fencing.

Arrangements have been made for storage of 500,000 tons of coal, a provision deemed advisable for a daily consumption of 10,700 tons.

Their factories have handled 1,330,000,000 pounds of cotton or 2,660,000 bales.

Production of nitric acid, 1,930,000,000 pounds, required the handling of 2,812,000,000 pounds of nitrate of soda.

Their sulphuric acid plants have produced 2,500,000,000 pounds of acid, requiring 922,000,000 pounds of sulphur.

Their factories have handled 216,500,000 gallons of alcohol, of which 86,600,000 gallons have been consumed and the balance recovered for re-use.

Individual dwellings to the number of 10,790 have been built. These, together with the accompanying hotels, boarding houses, women's dormitories, and bunk houses are capable of housing 65,000 persons. All of these dwellings are lighted, and furnished with purified water, from the company's plants, and are connected to modern sewage systems. In addition to these dwellings, their Engineering Department has built 570 community buildings, such as those to house the Young Men's Christian Association and Young Women's Christian Association, cafeterias, school houses, lodge halls, post offices, drug stores, banks and railroad stations, a total of 11,360 buildings, costing with the necessary streets, sidewalks, fire protection, etc., about $37,000,000.

The military powder factories constructed by E. I. duPont de Nemours & Co. and its subsidiary Dupont Engineering Company, cover 9,025 acres (14 square miles), equal to twice the built-up area of the city of Wilmington, Del. Incidentally their cost is about double the assessed value of Wilmington. Their annual capacity is 893,000,000 pounds of explosives or in carloads sufficient to extend from Baltimore to New York in continuous line.

At the height of their work the rate of yearly expenditures was three times as great as that of the construction of the Panama Canal.

The operation of the factories of this company has resulted in production of 1,466,761,219 pounds of military explosives of all kinds furnished to the United States and the Allied Nations. The importance of this work is better realized from the fact that this output is estimated at 40 per cent of the amount of explosives made throughout the world for the Allies during the war. During the four years of these operations the manufacturing departments have been continually ahead of deliveries required under contracts. The number of men employed in the military factories alone reached a maximum of 47,914, and organization built up from a total of 5,300 men employed in all departments of the company before the war.

Prior to the war the company had made comparatively little powder for foreign nations. The sudden call of the Allied Governments required the fitting of our form of powder, then almost unknown abroad, to guns designed to use other ammunition. This necessitated development of forty different powders for as many guns. These powders function under exacting specifications, though some of them average 42,000 pieces to the pound, each of these pieces is a perfectly formed cylinder with one or seven longitudinal perforations whose important dimensions require an accuracy of not more than 1/1,000-inch variation from the mean.

The ratio of the number of killed and injured and property loss to total men employed was far less than in preceding years, indeed was much less than in many reputed safer industries.

Haskell, New Jersey

THE left portion of the upper picture on opposite page shows a panoramic view of part of the smokeless powder plant of the duPont Company at Haskell, N. J. This plant was one of the important factors in the European War. It employed at the peak about 3,000 operators. It had a capacity of 210,000 pounds of smokeless powder and 40,000 pounds of guncotton per day. Other guncotton required in the operation was brought from Hopewell, Va. The plant had a community village adjoining it which was looked upon as an ideal industrial housing development. It had accommodations for 450 families, dormitories for 250 women, and club houses for 800 bachelors. There were modern and well-appointed service centers such as community houses, Y. M. C. A., gymnasium, and hospital. Welfare work was of the highest type.

The building on the extreme left of the picture and in the background is the B line ether house. To the right of this and in the background is seen the diphenylamine mixing house and the large building standing prominently further to the right is the alcohol rectifying house. Almost immediately adjoining this and in the center of the picture is seen a long, two-story building. This is the miscellaneous stores building and immediately behind it with the upper part showing, is the original water dry building. There were five water dry buildings on the plant. To the right of the miscellaneous stores building and a little in the background is the building used as fire department headquarters. Next to this and slightly in the foreground is the alcohol denaturing plant. The next building to the right and more in the background, being almost immediately in the rear of the small alcohol denaturing plant is the B line refrigerating plant and pumping stations. In the background towards the right of the picture is a new type water dry house. The building located on an elevation in the background towards the extreme right of the picture is the B line blending house. The large building in the foreground on the right, from which steam is coming, is the guncotton boiling tub-house, and the building in the foreground slightly to the left of it is the raw cotton dry house. In the background, center of the picture, are parts of B line first stage powder operating units.

The right portion of the upper picture on the opposite page is another panoramic view of the power area of the smokeless powder plant of the duPont Company at Haskell, N. J. Power for all purposes was generated at the plant. In its different forms it included live and exhaust steam, raw and filtered water, high and low pressure hydraulic water, compressed air, electricity and refrigeration.

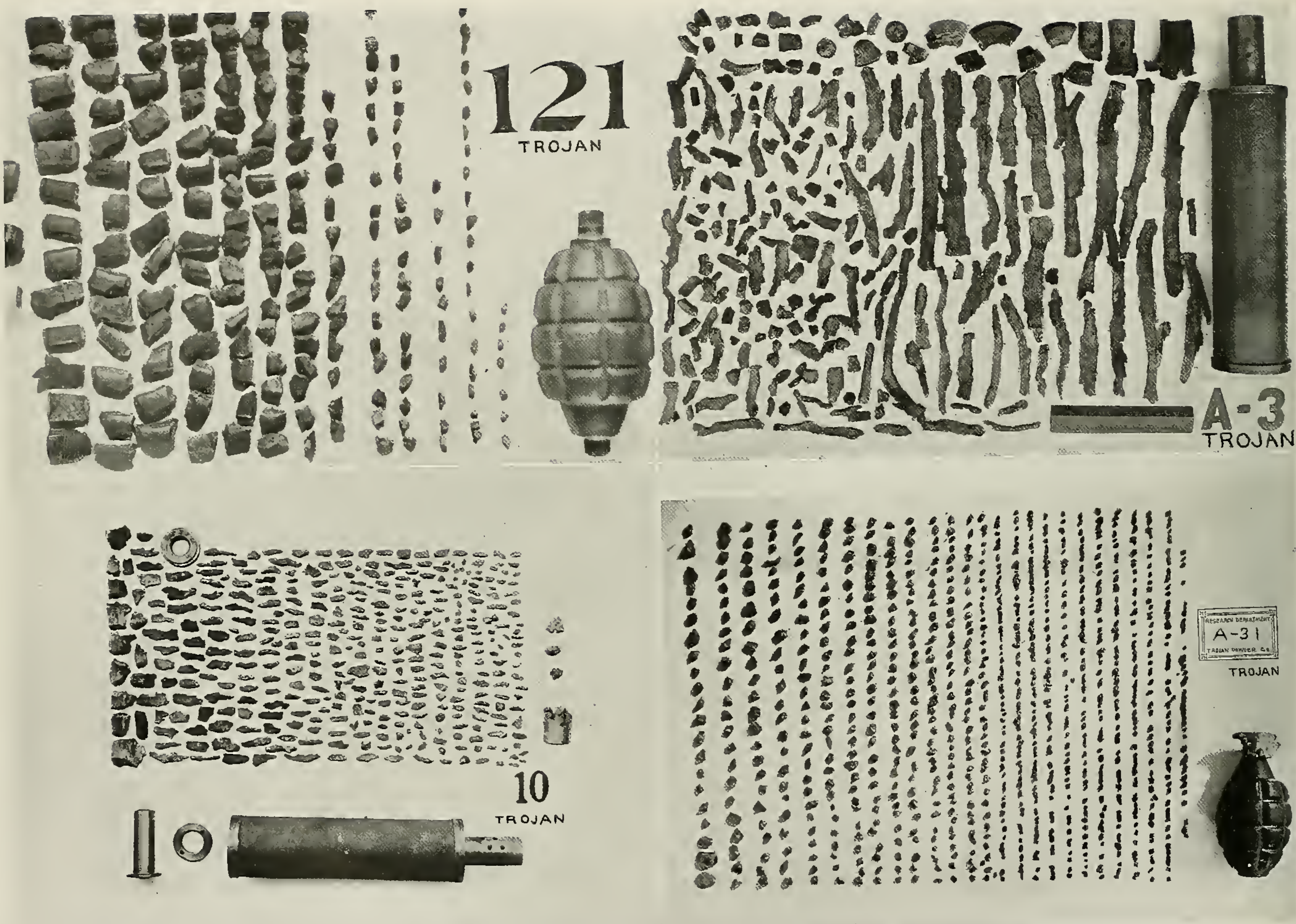
The total water consumption amounted to about 3,000,000 gallons per day, of which about 1,000,000 gallons was used for cooling purposes. Approximately 1,500,000 gallons was purified by gravity sand filtration system. All plant service water was taken from the Wanaque River, while water for drinking and special purposes, amounting to about 500,000 gallons per day, was taken from dug and driven wells and purified.

The boiler plant had a rated capacity of 6500 boiler H. P., and was operated normally at about 145 per cent of rating. The electric generating plant had a capacity of 1600 K. W. in direct current and 700 K. W. in alternating current. The refrigeration plant had a total capacity of approximately 375 tons per day. Hydraulic power was furnished at 3500 pounds pressure and at a rate of 300 gallons per minute, also at 300 pounds pressure and 450 gallons per minute.

The two buildings shown in the picture on the right of the stack are the boiler houses erected after the outbreak of the war. The building at the rear of the stack is the original boiler house. In the foreground, center of the view, is shown the electric power houses, pumping stations and filter plants. In the background, at the center, are the guncotton, beater and poacher houses. Towards the left are seen change houses and miscellaneous shops.

Seiple, Pennsylvania

The lower panoramic engraving on the opposite page shows general view of plant at Seiple (near Allentown), Pa., of the Pennsylvania Trojan Powder Co. and the Trojan Chemical Co.



Upper Left—Typical fragmentation Malleable Iron Hand Grenade, loaded with Trojan Grenade Powder

Upper Right—Steel Tube Trench Mortar Shell, loaded with Trojan Trench Mortar Explosive

Lower Left—Malleable Iron Trench Mortar Shell, loaded with Trojan Trench Mortar Explosive

Lower Right—Cast Iron Hand Grenade, loaded with Trojan Grenade Powder

Pennsylvania Trojan Powder Company

NOTE: It is a fact worthy of mention that the Pennsylvania Trojan Powder Company manufactured all of the grenade powder used in American grenades.

THE war activities of the associated Trojan companies (Pennsylvania Trojan Powder Co., California Trojan Powder Co., and the Trojan Chemical Co.) began with studies in connection with the manufacture of suitable bursting charge for hand grenades a few months after this country entered the world war. The necessity for an adequate supply of a powerful explosive suitable for use in the enormous number of hand grenades which were being planned for the use of the American forces abroad was evident, and research work was promptly undertaken along this line.

A supply of the malleable iron grenade bodies was obtained for preliminary tests, and intensive work was undertaken, for the purpose of determining the fragmentation characteristics of the explosives used up to this time as filling charges in hand grenades. The purpose of the work was to obtain, if possible, an explosive which would produce as satisfactory a fragmentation as crystalline T. N. T. In view of the enormous number of hand grenades which it was planned to supply for the use of the American forces, the available quantity of T. N. T. was seen to be insufficient for this use in addition to the many other fields for which it was to be used. At this stage in the work, the principal interests of the Ordnance Department in encouraging work on other explosives was to find an explosive which might be nearly, if not quite as satisfactory in fragmentation characteristics as T. N. T., and it is most doubtful if at the time there was the slightest thought that the work would lead to the development of a new explosive, surpassing T. N. T. in safety, availability and strength.

In all the preliminary tests the goal aimed at was to obtain as satisfactory a fragmentation as was produced by T. N. T. and the fragmentation produced by this material was everywhere recognized as the standard with which all other materials were to be compared. At this time T. N. T. represented the most perfect explosive which modern warfare had developed, but the problem was to obtain a material which would avoid diverting to hand grenades any considerable portion of the available supply of T. N. T., for, although the results obtained from T. N. T. were perfectly satisfactory, and represented the ideal to be aimed at, yet the other demands for this material would be such as to make it necessary to use in hand grenades some other explosive, provided a material could be developed which would be in any considerable measure as strong.

The necessary fragmentation pits, to enable hand grenades to be fired within a closed chamber and the fragments to be retained and counted, and also penetration boxes, to enable the velocity of the fragments produced to be determined by noting the distance which they would penetrate through spruce lumber, were quickly arranged, at Seiple, Pa., and a commencement was made for the many hundreds of tests which were made in the course of the following two months.

After having fired a sufficiently large number of grenades, using the standard charge T. N. T., and having carefully determined both the manner in which the tough metal of the malleable iron hand grenades was broken up and the velocity with which the particles were projected, the work began of developing an explosive which should be capable of giving results as nearly as possible equal to those given by T. N. T. As the work progressed, interest was excited from time to time by test shots with the new Trojan Explosive which appeared to be fully equal, not only to the average results produced by T. N. T., but even to the best results which that explosive showed. It was soon evident that the new product being formulated was not merely going to represent a substitute for T. N. T., but actually had such properties as made it superior to T. N. T. This result was one which could not be too readily accepted, in the absence of tests of a most convincing character, but as the work progressed this evidence accumulated in ever-increasing amount. On December 3, 1917, the accumulated data from the large number of tests made was brought together in the form of a report, under the title "Relative Efficiency of Trinitrotoluene, 80-20 Amatol and Trojan Grenade Powder, as Grenade Filling Charges."

In this report the results of a large number of comparative fragmentations produced by crystalline T. N. T., 80-20 Amatol, 50-50 Amatol and Trojan Grenade Powder were compared, and the results showed conclusively the superiority of the new Trojan explosive for grenades.

Formal tests were made soon after, and the results were so convincing that when shortly after, a contract for a considerable quantity of the new explosive was made with the Pennsylvania Trojan Powder Co.. it was made a part of this contract that every lot of the new explosive, before acceptance, should be tested in hand grenades in comparison with other similar hand grenades loaded with T. N. T., and that no lot should be accepted which did not, by this most severe test, show superior results to these produced by the T. N. T.

It is interesting to note at this point during the entire life of this contract, covering sufficient Trojan Grenade Powder for the loading of many millions of grenades, no lot of the powder ever failed to show its superiority in this comparative test in comparison with grenades loaded with crystalline T. N. T., which up to then represented the most perfect explosive which military science had developed.

With the appreciation that a new explosive equal and even superior to T. N. T. had been developed, came the instant recognition of its importance, and steps were taken to arrange for increased capacity to meet the military needs. The Engineering Department of the Pennsylvania Trojan Powder Company then entered upon the work of developing in both their plants in California and in Pennsylvania the necessary daily capacity of the new explosive. Extension of existing capacity and new construction for additional capacity was soon under way, but the increased requirements of the new explosive as its usefulness in other lines than as a grenade explosive became recognized, kept pace with the increased building program.

With the progress of the war, the use of trench mortar shells for offensive and defensive purposes, saw an enormous extension. For many miles the front line trenches were sufficiently close to each other to make the use of three-inch and six-inch trench mortar shells decidedly effective, while the efficiency of these shells in destroying barbed wire entanglements, and in defense against oncoming troops was thoroughly understood with the progress of the conflict. Part of the military program of this country involved the sending to the seat of war a vast number of three-inch, six-inch and larger trench mortar shells. To satisfactorily fragment a trench mortar shell, with the production of fragments of maximum efficiency requires an explosive both of high power and of great brisance; research work was commenced to determine the possibility of adapting the grenade powder formula to this new line of work. Comparative tests made on the testing field of the company soon showed that here, as in the hand grenade, the newly developed Trojan Explosive gave superior results to those obtained with the fused T. N. T. which was at that time the standard loading charge. The informal tests thus made were followed by official tests at Aberdeen made on March 16th, 1918, at which the new Trojan Trench Mortar Shell explosive was tested in comparison with similar shells loaded with the standard charge of fused T. N. T. The test was a complete triumph for the new explosive, the behavior of which was officially rated at 100 per cent, and comment was made of the fact that while showing all of the good features of T. N. T., it gave in addition decidedly better fragmentation results in the fragmentation test, and noticeably larger craters in the crater test.

Shortly after these tests arrangements were made for suitable extensions with the trench mortar shell program, and Trojan Trench Mortar Shell Explosive became the authorized explosive for trench mortar shell, and until the cessation of hostilities the loading of the three-inch trench mortar shell with the new Trojan Explosive went forward with great rapidity.

The research and laboratory facilities of the Trojan Powder Company were put at the disposal of the Ordnance Department for a considerable number of miscellaneous lines of study, and this work was conducted in co-operation with officers from the Engineering, Trench Warfare, and Aerial Bomb Divisions of the Ordnance Department. Among the many interesting lines of work which were thus taken up in co-operation with different divisions of the Ordnance Department were studies on the cause of prematures in rifle grenades, studies as to the functioning of fuse for high explosive shell and for trench mortar shells, studies of the booster and detonator assemblies of drop-bombs, and many other similar lines.

At the signing of the armistice the plants of the Trojan Powder Company had a capacity of more than 50,000,000 pounds per year of Trojan Grenade Powder and of Trojan Trench Mortar Shell Explosive, and plans were under way to still further increase production of both of these explosives, and of new explosives still under development for use as bursting charges in aerial drop-bombs and for other purposes. These new explosives, representing increased strength, efficiency and safety as compared with the explosives formerly used as the standard bursting charges for hand grenades, mortar shell and like military supplies, represent a part of the fruits of America's entry into the war. The Trojan Powder Company did its "bit," just as thousands of other American companies, and millions of America's boys did theirs, and the net result of all of these efforts was to bring the world's greatest war to an end.

Nitro, West Virginia

General view of Smokeless Powder Plant at Nitro, West Virginia, showing operating area and employees' bungalows. The right-hand portion of the

Nitro, West Virginia

The right-hand portion of the upper picture shows the employees' bungalows to the left, and to the right the homes of Superintendents and officials.

The Hercules Powder Company

THE war called upon American industry to accomplish the impossible. Possibilities must be gauged by past performances to a large extent, and if we apply this scale to our industrial accomplishment, we find that under the spur of the country's necessity, impossibilities were almost daily turned into realities. We are still, at this writing, too near to the scene of the industrial battle to give a correct estimate of it. There is no dearth of material, but it is difficult to get the proper perspective as it passes in review. When confronted by such an array of achievements, each of which seems to merit recording for all time, writers of today must inevitably be misled as to the true importance of some of them.

Now we are overwhelmed with tactics. The future historian will be concerned only with the strategy employed and the generals who devised it.

In the present instance the tendency to over-emphasize details has been hard to avoid, but an earnest effort to do so has been made. Figures of production claim a prominent place in the study of the war activities of the Hercules Powder Company. They are, of course, the final measure of the assistance rendered to the country and the cause. But taken by themselves, or even when coupled with the facts about construction and operations that made them possible, they do not give the whole story.

When all is said and done, and when due acknowledgment has been made to the men who carried out the manufacturing operations, there remains the most important factor of all, which cannot be expressed by facts and figures—the executive factor. This is what we do not see as we go through the records. Perhaps its influence is most plainly indicated when we study the organization problem which confronted the Company in mention, and the way in which it was met. Before the war 1,500 people were employed by the Hercules Powder Co. This had increased to 6,000 when the United States entered the conflict, and before it was over 15,000 were on their rolls. Certainly nothing contributed more effectively to that Company's success than the skill which must have been exercised to bring about cohesion in this rapidly expanding force. There must have been some quality in the skeleton organization about which the great new machine was built that was unusual; that does not often exist to anything like the same degree in large companies. In spite of great dilution through the influx of technical men from many divergent fields of chemical and engineering endeavor, and workmen from almost every walk of life, these pivotal men quickly imbued the new organization with their energy, and with a fine spirit of co-operation.

Production on such a prodigious scale as that with which we are dealing requires an infinite amount of labor quite aside from that which will be considered in connection with plant operations. No figures can serve to express it. The final result, the finished product, the victory itself, would have been impossible without it.

Neither can figures and statistics explain why it was that during the winter of 1917-18 when the inability of the railroads to handle the enormous quantities of freight in the eastern part of the country owing to the heavy snow-falls and the ice, caused plants to shut down right and left, not one of the Hercules Powder Company's operations was stopped for want of coal or any of the raw materials entering into explosives. The materials necessary to make powder were always on hand. In connection with Government work, approximately 40,000 carloads of material were handled in and out of the plants. A detailed study of the material which it devolved upon the Purchasing Department to secure, would soon become tedious. Taking only the important raw materials, the figure in pounds used runs into *billions!* This probably means little to most readers, but the story has already been told. The material was there, and the plants never had to shut down for want of it.

There is another important phase of the work, possibly the most important, which cannot be adequately presented. Reference will be made to new methods devised by The Hercules Co. These were presented to the Government for its use and passed along to other manufacturers engaged in similar work.

The principal war materials supplied by the Hercules Powder Company to the United States Government were Smokeless Powder, T. N. T., Nitrate of Ammonia and Black Powder. The potash required to produce the latter was also manufactured by the Company in a unique way, which will be described later. Before the European War started, the Hercules Company was engaged in manufacturing commercial explosives only. Since then its Smokeless Powder plants have been enlarged from a capacity of 1,500 pounds per day to

A portion of one of the Smokeless Powder lines at the Kenvil Plant of the Hercules Powder Company

215,000 pounds per day! It has supplied enormous quantities to the United States, as well as to the Allies. The Company started manufacturing T.N.T. with one plant capable of turning out 20,000 pounds daily, and at the signing of the armistice it had fourteen plants in operation, with a total capacity of 280,000 pounds per day. The manufacture of Nitrate of Ammonia and Black Powder was also greatly increased. In normal times its capacity is two and one-half million pounds yearly. During the war it was raised to six million pounds!

In 1914 we were dependent on Germany for potash suitable for conversion into pure saltpetre which is absolutely necessary for the production of Black Military Powder. Long before September, 1918, this Company was extracting potash from kelp at the rate of five hundred tons per month, a quantity sufficient to supply all United States Army needs for Black Powder. Chemicals which were used medicinally and also some which contributed to the fulfillment of other parts of the military program were secured from the same source as by-products.

Before the war, the United States could not produce over 500,000 pounds of acetone monthly, and this was increased by 1,400,000 pounds per month through the efforts of the Hercules Powder Company alone.

Smokeless Powder

The Hercules Powder Company's Smokeless Powder plants are located at Kenvil, N. J., and Gillespie, N. J. From a small plant for the production of Smokeless Sporting Powders, Kenvil had been enlarged in 1916 to produce 3,000,000 pounds of Cordite monthly for the British Government. As this is not used by the military or naval forces of the United States, the facilities for making it, and the skill in its manipulation which the organization had developed, could not be put completely at the service of the Country.

Cordite is known as a double base powder, because it is composed of two explosive ingredients, gun-cotton and nitroglycerin. The Pyro powders used by the United States derive their propellant force from gun-cotton alone. For this reason all their nitroglycerin equipment became useless. The Cordite presses had to be remodeled or replaced, the mixing equipment had to be altered, and the cutting, blending and packing arrangements entirely replaced. Besides utilizing and transforming the Cordite machinery, this Company designed and constructed new equipment which had a greater unit capacity than any existing types, and which made possible increased output with a minimum outlay in time and labor. Methods of solvent recovery, water-dry, air-dry and blending have been greatly facilitated and simplified by improvements made by the Hercules Company.

Finishing presses were remodeled to increase safety as well as speed of operation. Important changes were made in the solvent recovery cars which reduced the time required for recovering residual ether and alcohol from 120 hours to 60 hours for each carload weighing 2200 pounds. This alteration affected existing equipment only. An even more important innovation was introduced in connection with additions to the plants that involved entirely new constructions, instead of adaptation and remodeling. This eliminates the solvent recovery cars entirely. It is a combined solvent recovery and water-dry system, through which the time required between the beginning of solvent recovery and the end of water-dry is reduced to 144 hours as against 264 hours, under the old method, and 204 hours with the improved solvent recovery cars.

The old method of air-dry in which the powder was placed on racks in a long building and which was one of the most prolific sources of fire, was superseded by a continuous air-dry system. This makes use of the principle used in grain dryers and while the old method took a maximum of forty-eight hours for the process, the new one requires only six hours.

One of the greatest departures from previous practice is shown in the new design of blending house. Two methods of blending had been used, both of which were somewhat laborious and one of which was attended with a certain amount of danger. The new device is a twelve-sided bin with partitions dividing it into twelve equal triangular sections, holding a total of 125,000 pounds of powder. These compartments have sloping bottoms, drawing all to a point at the center where twelve gates are controlled by ropes to a lever-bank like a chime-ringer's "keyboard." Beneath the gates a conical hopper is swung on a scale, so that by pulling a handle and watching the dial of the scale, the operator may draw and weigh from any bin a quantity of powder from one pound to 1200 pounds. By drawing a small amount from each bin in turn, a mixture is dropped into the hopper, which further blends its contents by discharging through its bottom into the powder cart waiting beneath. This worked very well, and gave the required blends with a much less expensive structure and less danger.

Building used for the continuous Air Dry System. One of the improved processes developed by the Hercules Powder Company, Kenvil, New Jersey. Note the chutes for rapid exit in case of fire.

Girls Sorting Out Imperfect Grains of Smokeless Powder. Hercules Powder Company's Plant, Kenvil, N. J. Upper right-hand view. shows Smokeless Powder manufacture under difficulties—during the severe winter of 1917-18; great banks of snow are seen toward the approach to the building in background.

One of the Box Packing Houses, Kenvil, New Jersey, T. N. T. Plant—illustrating type of barricade used to confine the damage in case of accidents.

At the Hercules Union plant, near Gillespie, N. J., additional apparatus and equipment were provided. Changes here were similar to those at the Kenvil plant. These affected the finishing presses and the solvent recovery cars. On new construction the continuous air-dry and improved blending house were installed.

Government Smokeless Powder Plant
Nitro, West Virginia

In May, 1918, when the activities which have just been described, and both construction and operation were in full swing, the Government requested the Hercules Powder Co. to assume control and operation of the great plant then in process of construction at Nitro, W. Va. The problem presented by this request was one which might well cause hesitation on the part of any company that had already expanded to a degree that would ordinarily be considered dangerous. This plant was being designed to produce in the neighborhood of 625,000 pounds of Smokeless Powder daily. To operate it would require a staff of five or six hundred technical men, and from ten to twelve thousand laborers. Not the least difficult part of the undertaking would be the management of a town of from 25,000 to 30,000 inhabitants, including the administration of schools, stores, hotels, restaurants, places of amusement, and all the civic activities found in any city of equal population. This was a staggering proposition to put before a company of this size, but when the Ordnance Department represented that however ill-equipped in point of numbers the Hercules people were to undertake the task, they were in a better position to do so than any other company in the country, the officials of that Company did not hesitate long about assuming this immense responsibility.

Steps were immediately taken to build a new organization around a little band of experienced men drawn from all branches of the business. That these men could not well be spared, is easily understood. They were sorely needed on the work from which they had to be taken, and their removal placed a severe strain on the remaining forces which were already taxed to the utmost.

Fortunately, the situation called for a gradual upbuilding of the personnel at Nitro. The first acid unit was completed for operation in July. By this time the nucleus of a well co-ordinated body of operatives was on the ground, and this was enlarged to keep pace with the progress of construction. The plans for this plant contemplated five powder lines, each with a capacity of 125,000 pounds a day, which if it had been completed, would have meant an output of 15,625,000 pounds in a month of twenty-five working days! However, at the time the armistice was signed, no completed lines had been turned over for operation, and such units as were producing were still in the preliminary try-out stages. The total production during an operating period of about a month was 4,500,000 pounds, but during this time new units were gradually being taken over, and it was not until near the end that operations became of any importance from the standpoint of production. At this time the Hercules organization at Nitro consisted of about four hundred technically trained men and women and six thousand laborers.

Manufacture of T. N. T.

Shortly after the United States entered the war the Government approached the Hercules Company with a suggestion for making T. N. T. at Kenvil, N. J.; prompted in this largely by the highly succeessful operations of this character which had been conducted at their Hercules, Cal., plants. T.N.T., or Trinitrotoluol, is made by the nitration, in three steps, of toluol, a coal tar derivitive, and thus gets its name. It is used as a bursting charge for high explosive shells. Agreements were soon reached, and work was started on two plants in October, 1917. These were completed early in 1918, and have a capacity of 1,000,000 pounds of crude, or 900,000 pounds of refined T. N. T. per month.

All the operations of the Hercules Powder Company both before and after the entrance of our country into the war, have been remarkable for the small amount of damage to life and property by explosions, and with which they have been carried out. On one of the T. N. T. lines at Kenvil, an explosion resulted from a fire which started in a nitrator, and practically the whole line was destroyed. This happened in July, 1918, when production was badly needed, but it caused a minimum of delay. The plant was rebuilt, and put into operation in thirty working days, which is probably a record for construction of this character.

In April, 1917, there were four T. N. T. plants at Hercules, Cal. Another was finished in January, 1918, bringing the monthly capac-

ity up to 2,500,000 pounds. This immediately became available for the country's needs. However, this was not sufficient, and in 1918 work was started on seven new lines, which were in partial operation three months later, and all of which were running in September. These additional lines increased the output at Hercules to 6,000,000 pounds of crude T. N. T. per month.

To put these new plants in operation, it was necessary to develop additional water supply, which was done by running six miles of eight-inch pipe to connect with the mains of a local water company. Storage had to be provided for toluol, acids, nitrate of soda, sulphur and for finished products. A contact type sulphuric acid plant was built to produce 6,600,000 pounds of fuming sulphuric acid per month, and a nitric acid plant having twenty-two acid stills and a capacity of 5,310,000 pounds monthly. In connection with this, new features for unloading and handling nitrate of soda were installed. The experience gained on seven other lines — five at Hercules and two at Kenvil — resulted in a design which made this one of the most efficient T. N. T. works in the world. It is also one of the largest.

Black Powder

The Hercules Company has numerous plants for the manufacture of so-called "B" Blasting Powder, but only one for Rifle Powder, suitable for military purposes. This is used as a bursting charge for shrapnel shells, for making primers and fuses, and as an ignition charge. The processes for manufacturing these powders do not differ greatly, nor does the required equipment. The principal difference is that nitrate of soda is combined with charcoal and sulphur to produce "B" Powder, while potassium nitrate is used in the Rifle Powder.

Nitrate of soda absorbs moisture much more readily from the air than potassium nitrate. On account of this characteristic, the powders containg the latter are more stable and can be handled and stored successfully for longer periods and under less advantageous conditions, but they are much more dangerous to manufacture. Even with all the safeguards that modern engineering skill has devised, it has never been possible to eliminate fires and explosions. However, the plants are so laid out that when these occur a relatively small amount of material and equipment is affected, and the lives of very few people are endangered at any one time. Nevertheless, workers accustomed to the production of "B" Powder are usually afraid of the Rifle Powder Process. There is a certain amount of superstition connected with this fear, which greatly exaggerates it.

When an ouput of Black Military Powder was called for, considerably in excess of the capacity of the Hercules plant at Valley Falls, N. Y., the chief difficulty involved in changing the "B" powder plants at Ferndale, Pa., Youngstown, O., and Hercules, Cal., over to the manufacture of this product, arose from this fear on the part of their operatives. The whole situation was complicated by rumors of spies, and some accidents which were actually traced to incendiaries, took on exaggerated significance in the minds of the workers. However, by transferring as many experienced men from the Valley Falls plant as could possibly be spared, and by employing the utmost tact with the men, and care with the operations, it was possible to hold their operating forces together and keep the plants running with very few interruptions. A capacity of 850,000 pounds per month was reached, against a normal capacity of 167,000 pounds.

The shortage of potash which has been acute in this country since the beginning of the European War might have seriously interfered with Black Powder production, had it not been that the Hercules Company was in position to supply its own needs through the extraction of this material from kelp, of which a description will be given.

Nitrate of Ammonia

Modern warfare calls for such a prodigious expenditure of high explosive shells that in spite of all that was done to increase production of T.N.T., which is probably the best explosive for this purpose, it was necessary to employ substitute in order to meet the munitions program. The best known and most satisfactory of these is Ammonium Nitrate, which, mixed with T. N. T., proved very effective, the mixture being known as Amatol. Ammonium Nitrate is produced from the ammonia liquors that are secured as a by-product from gas works and other operations involving the distillation of coal.

The utilization of these liquors for the manufacture of this product is a part of the normal operations of the Hercules Powder Company, as ammonium nitrate is used in many of the commercial grades of dynamite. However, production for this purpose had never exceeded the Company's own needs, and this could not be interrupted, because

The San Diego Kelp Plant

This plant was designed, primarily, to procure acetone for the manufacture of British cordite, prior to the entry of the United States into the war. This panoramic view of the great Kelp Reducing Plant of the Hercules Powder Co., at Potash (near San Diego, California), shows in the left background the 156 kelp digestion tanks, each with a capacity of 50,000 gallons. In the center of the picture at the right is the converter building of the acetone group, with the carpenter shop and laboratory on the left. Back of these are the steam dryer, heat transfer, centrifugal crystallizer and evaporation buildings. On the right of the picture in the foreground is the generator division of the acetone group, back of which are the power and warehouses, and in the background the direct heat dryer.

the war activities of the country were as much dependent on the minerals mined with dynamite as on military high explosives.

Because its energies were fully engaged in large Smokeless Powder and T. N. T. operations, the Hercules Company could not undertake to build new plants for the manufacture of Nitrate of Ammonia on a large scale. However, in April, 1918, that Company agreed, at the suggestion of the Government, to increase its output from existing facilities to the utmost. As a result, very considerable quantities were produced, in addition to normal output.

Chemicals from Kelp

In connection with Cordite, manufactured for the British Government, which has been previously mentioned, the Hercules Powder Company designed and built a plant near San Diego, Cal., between January and June, 1915, which is unique among the world's industrial establishments. Its primary purpose was to supply acetone, a solvent necessary to the production of Cordite. After the United States entered the war, this plant proved very valuable to our Government, supplying needed materials that were not even thought of at the time it was built.

In past centuries kelp has frequently served both for potash and iodine production. However, such utilization has been on a relatively small scale. When compared with the plant in which the Hercules Company extracted these and many other products from the giant sea-weed, previous efforts have been relatively insignificant.

The novel conceptions involved in this enterprise make it worthy of further description. The kelp, growing in long streamers in the shallow rocky waters of the California coast, is cut and gathered by three great harvesters, which hoist it to macerators upon their decks and transfer the liquid mass to storage tanks below. Seven large barges are used to collect the cut from the harvesters, which stay constantly at sea and operate day and night. The macerated sea-weed is pumped into the barges and transported to the wharf in the sheltered waters of San Diego Bay.

Here pumps of special type suck it from the barges past strong magnets which remove all steel and iron objects that would endanger the machinery through which it passes later. Through a half mile of pipe the liquor finds its way to tanks where it is fermented. Under carefuly regulated temperature conditions, bacterial action ensues, resulting in the liberation of ascetic acid and potash salts. After neutralization with lime to change the ascetic acid into acetate of lime, or calcium acetate, settling, filtration, and evaporation bring the product to a clear syrupy liquid, from which calcium acetate is precipitated by boiling and potash by cooling.

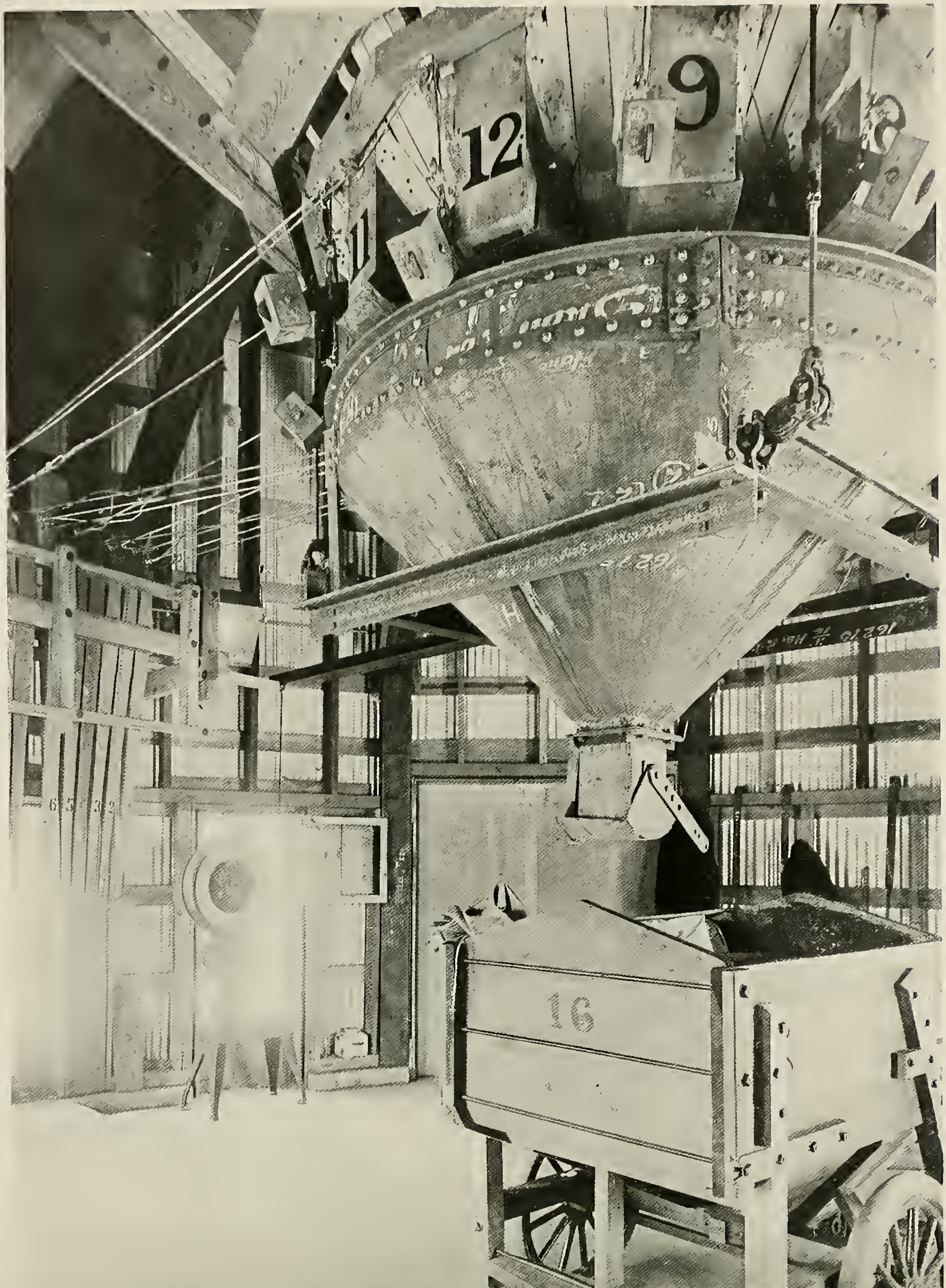
The potash, in the form of potassium chloride, is shipped away and converted into potassium nitrate, for use in the Black Powder already mentioned. The calcium acetate yields acetone consequent upon roasting in retorts, and rectifying the vapors. In this rectification process, other solvents than acetone are separated. Some of these were used in connection with cellulose nitrate or nitrated cotton, for the manufacture of lacquers of various colors, which formed a covering for shells and shell cases. This served the purpose of identifying the various varieties by the colors, and formed a non-fowling protective covering. Other solvents combined with cellulose nitrate formed the coating for aeroplane wings, which is known as aeroplane "dope." The ascetic anhydride mentioned below was also used in manufacturing the non-inflammable "dope" for the wings of battle planes.

Not all the products from this plant were used with destructive agents. Two, at least, were sent on healing errands. From some of the acetic salts was made acetic anhydride, a water-white liquid used in the manufacture of acid acetylo salicylic or of aspirin, which was so greatly in demand by all our medical units during the epidemic of Spanish influenza. Other medicinal products of the plant are iodine and bromine, which have been produced in a state of high purity.

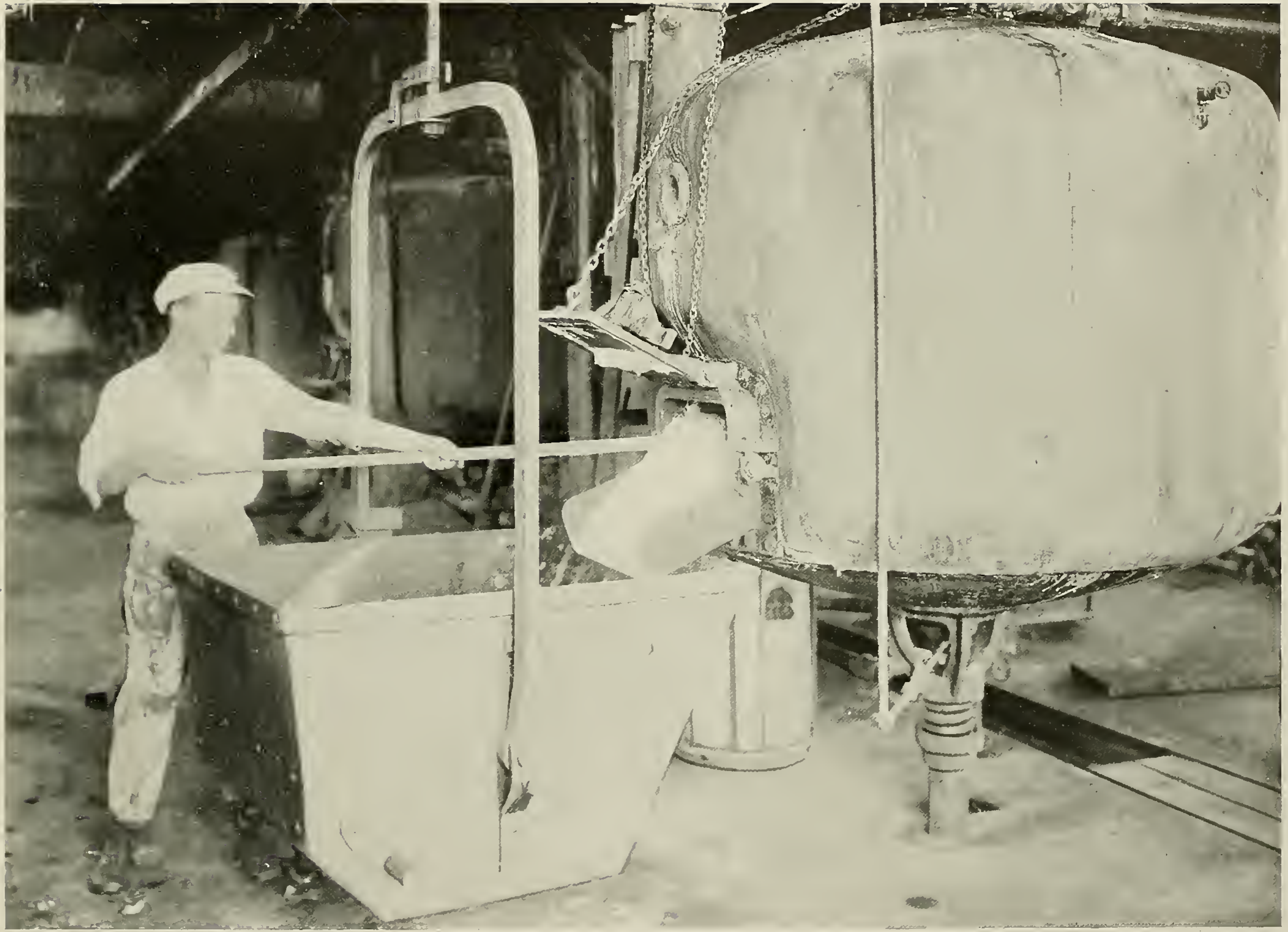
Experimental Work

Coincident with construction and production a large amount of experimental work was carried on. The practical results of most of this have already been described in connection with new devices installed for the manufacture and handling of Smokeless Powder. Some of the other work which was not brought to a complete fruition in time to be of actual service in the emergency is nevertheless worthy of mention. Perhaps the most important was the discovery of a means of curing Smokeless Powder by which solvent recovery cars and combined solvent recovery and water-dry houses could all be eliminated. This method contemplated plunging the powder directly from the cutting machine into a bath of alcohol properly treated with

(Continued on page 37)



Ingenious Blending Device, Kelp Reducing Plant. Operated by means of the organ-like levers seen on the left, the operator watching the dial, any desired quantity up to 12,000 pounds can he introduced into any desired bin. After the several ingredients have been so introduced, they are blended in the funnel shaped hopper below and "shot" into the wagon beneath the device.



Removing Potash Salt from Crystallizing Kettle. Kelp Reducing Plant, Hercules Powder Co., San Diego, Cal.

Employees celebrating the first step towards making us independent of Germany for Potash suitable for military powders.

other ingredients to regulate its action. This withdrew the ether portion of the residue solvent, and the alcohol portion was afterward removed by a water bath. This new method would make possible a great saving of time in drying, and was approved by the Ordnance Department. This invention was presented to the Government and through it to other makers of Smokeless Powder who were preparing to put it into execution, so that only the cessation of hostilities forestalled a revolutionary change in this branch of Smokeless Powder manufacture.

A new Pyro powder was developed for the army pistol which proved superior to other Pyro pistol powders in a number of characteristics. One of its most important advantages is that it burns absolutely clean.

The trench mortar was one of the most effective weapons developed during the war for throwing short-range shells and bombs. The projectile for the Stokes type is on the end of a stick, and the propelling charge is strung on this. This powder charge was sewed in small silk tubes joined at the ends to form a ring, the number of rings determining the range. The charge is ignited by a shotgun shell placed on the end of the stick, which strikes a firing pin at the bottom when the shell is dropped down the muzzle of the gun. In endeavoring to improve this ammunition, the Company developed a knitted tube to replace the stitched one previously used, thus greatly facilitating manufacture and loading.

In large calibre rifles, such as the ten and twelve-inch, a priming charge is necessary in order to secure quick ignition on account of the large amount and the large size of the powder. Black Powder is usually used for this, but at the request of the Government, the Hercules Experimental Station developed a smokeless ignition powder which was pronounced, after tests at the Aberdeen Proving Grounds, superior to other powders made for this purpose.

Making Dynamite Under Difficulties

There is a story that makes a fitting ending to a chapter full of really great achievements. Corn meal and wheat flour are regularly used in dynamite, and dynamite is just about as essential a commodity, in war or peace, as it is possible to find. Nevertheless, the Food Administration, pursuing its policy of asking why, whenever it found food products being used for other purposes than sustaining life, suggested that it would be desirable to find a substitute. Under the circumstances the Company might have pointed out with much justification that research men were scarce and that all who were available were occupied on Government work. Instead of this, however, they immediately set out to discover a new ingredient for dynamite.

Soon a process for grinding cocoanut shells was perfected and experimentation proved that meal from this source was satisfactory. When the Government commandeered all the cocoanut shells in the country for use in chemical warfare, and this had to be abandoned. Next almond shells were tried, but by the time a method for using them was found, the Government again stepped in and took the almond shells. Peach pits were then tried and the same thing happened. Nothing daunted by these exasperating set-backs, work was started on pecan shells in the east and walnut shells in the west. This proved successful, and as a result nut shell meal has been replacing that made from corn and wheat for some time. The saving was not large compared to the Food Administration's total program for reduced consumption of cereals, but this incident is a final illustration of the whole-hearted way in which this Company grasped every opportunity to help win the war.

View of Village from Havre de Grace, Md. Ammonium Nitrate Plant, Perryville, Md.

Atlas Powder Company

THE Atlas Powder Company are manufacturers of explosives, chemicals and detonators. Fifteen large plants, located at important trade centers throughout the United States, are engaged in the manufacture of these commodities, so necessary in war. Four of the largest operations, located at Atlas, Mo., Reynolds, Pa., Senter, Mich., and Hopatcong, N. J., are engaged exclusively in the manufacture of high explosives and chemicals (ammonium nitrate, acids, etc.).

At the beginning of the war the Atlas Powder Company was the largest manufacturer of Nitrate of Ammonium in the United States. This chemical is employed in the manufacture of the so-called Ammonia class of high explosives and is the principal ingredient of Amatol—the well known charge for high explosive shells.

Before the United States entered the war, France and Italy turned to America for great quantities of this all-important material and the Atlas Powder Company supplied their requirements to the limit of its capacity.

During the year 1915, the Atlas Powder Company manufactured for the war use of the allied governments over 13,000,000 pounds of Ammonium Nitrate, 14,000,000 pounds of acids and 2,500,000 pounds of nitrocotton. The following year the demands for these materials were greater, and during 1916 there was shipped for the account of the Allies over 90,000,000 pounds of acid (sulphuric and nitric) and over 25,000,000 pounds of Ammonium Nitrate.

In 1917 the shipments were 75,000,000 pounds of acids and 37,000,000 pounds of Ammonium Nitrate; besides contracts were awarded the Atlas Powder Company by the United States Government in the year 1918 for 262,500,000 pounds of Ammonium Nitrate and 105,000,000 pounds of acids.

When the United States entered the war, the demand for Ammonium Nitrate was so great that the Ordnance Department found that the then present production of this chemical must be increased by many times, and because of the limited supply of raw materials from which it was made (in the United States) the problem of how to do so was a very serious one.

The British Government was and had been manufacturing Ammonium Nitrate by a distinctive and newly developed process which utilized certain raw materials hitherto considered unavailable.

The Atlas Powder Company, being the largest producers of Ammonium Nitrate in America, were requested by the Ordnance Department to send a representative to England to thoroughly investigate the British method, and to ascertain if it would be practical to use this process in the United States. This request was made November 10th, 1917, and immediately the Atlas Powder Company dispatched four representatives instead of one. These men—Messrs. James T. Powers, G. C. Given, W. D. Craig and P. W. Parvis—accompanied by Major C. T. Harris (since Colonel), of the U. S. Ordnance Department, made a quick, but thorough, investigation of the only British plant using the process, and returned to the United States, December 23, 1917. They reported to the Ordnance Department that the "direct process" of manufacture was extremely complicated, being an application of what chemists term the "phase rule." Unless the chemical control was maintained with the utmost accuracy, any of seven different chemical compounds other than Ammonium Nitrate, and all unfit for war use, might result from the ingredients used in the process.

The process worked admirably in England because of the ideal climatic conditions, there being little variation in temperature. Under climatic conditions which prevailed in the United States, however, Ammonium Nitrate could not be produced practically and economically by the English method. The research laboratories of the Atlas Powder Company determined that the process could only be used if it were possible to "manufacture" a suitable climate, since there was no location in the United States where proper atmospheric conditions could be found.

The situation was that Ammonium Nitrate must be made to win the war and the handicap of climatic inequalities must be overcome. The Research Laboratories of the Atlas Powder Company, in conjunction with the Ordnance Department, therefore undertook the task of duplicating the work of the English plant under what appeared to be impossible conditions. They devised a system of air conditioning which would make the plant absolutely independent of all the caprices of the weather.

Final decision to proceed was given by the Ordnance Department March 1st, 1918. A contract was signed with the Atlas Powder Company for the construction of a plant to produce 100,000 tons Ammonium Nitrate yearly.

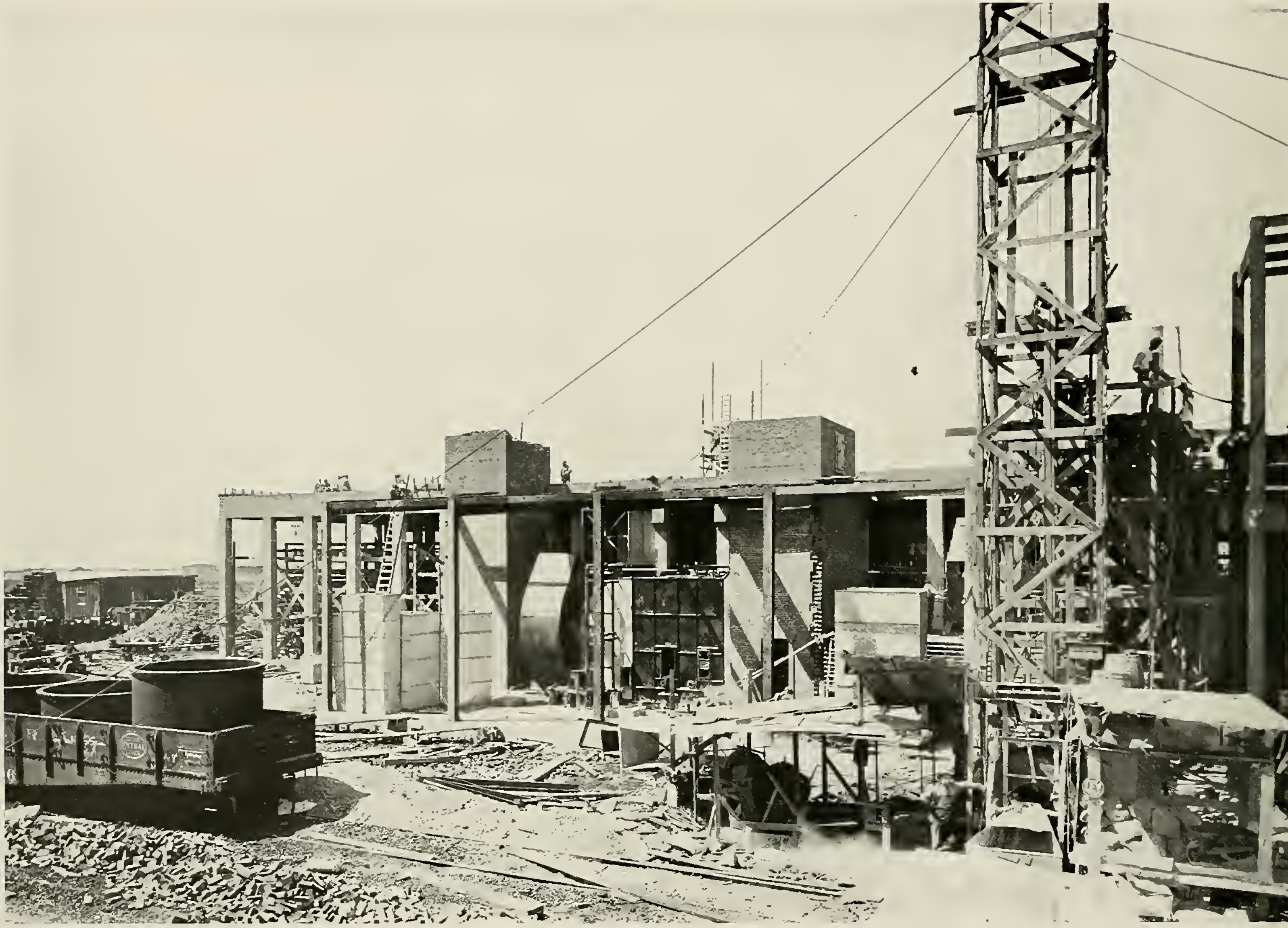
(Continued on page 47)

Village Under Construction. In the foreground are Guard Barracks, Guard House and Pay Booths. Ammonium Nitrate Plant, Perryville, Md.

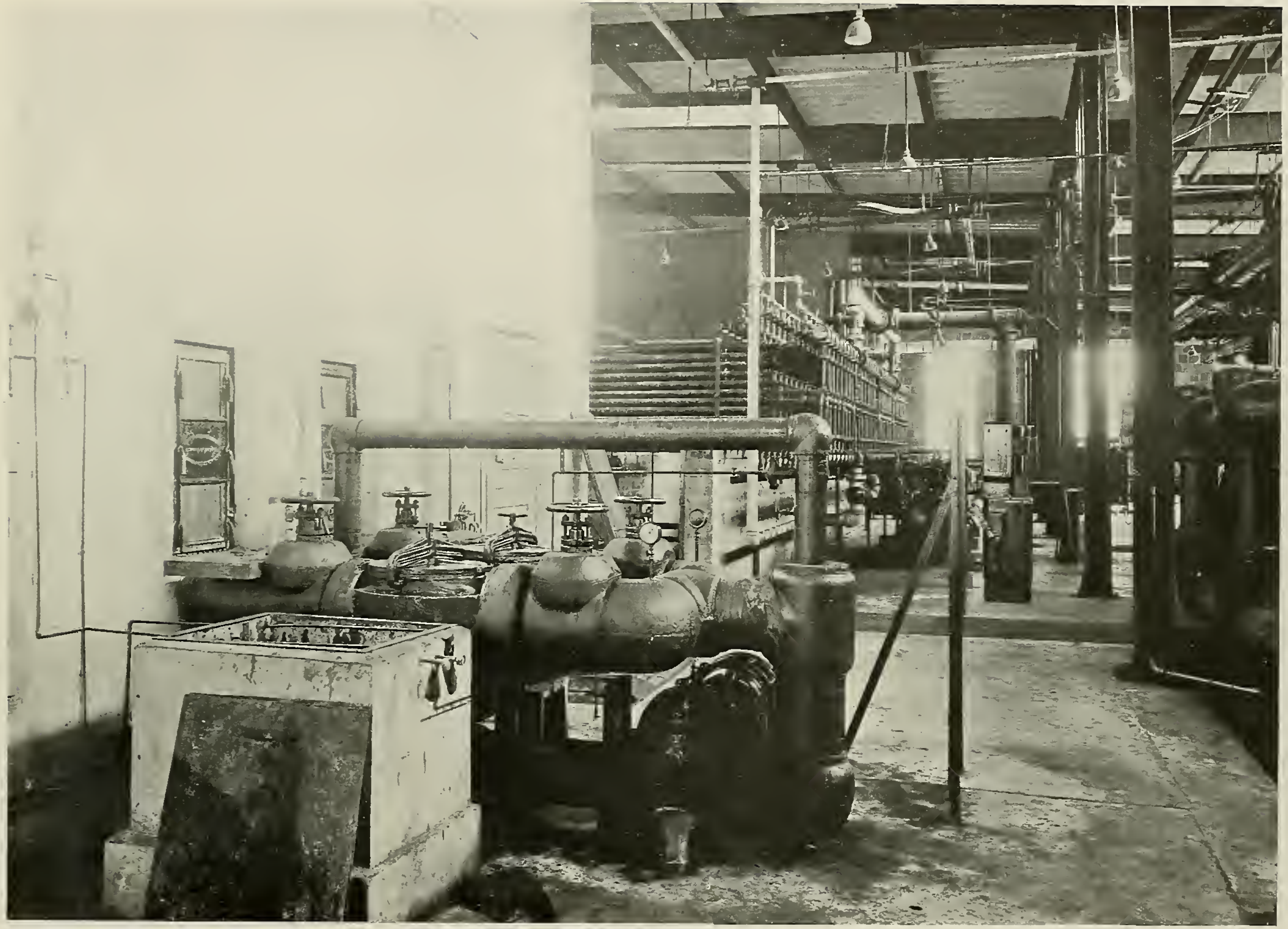
Main Office, Commissary, Part of Bunk Houses, Change House and Boarding Houses during construction. Ammonium Nitrate Plant, Perryville, Md.

View of part of construction of Bunk Houses. Ammonium Nitrate Plant, Perryville, Md.

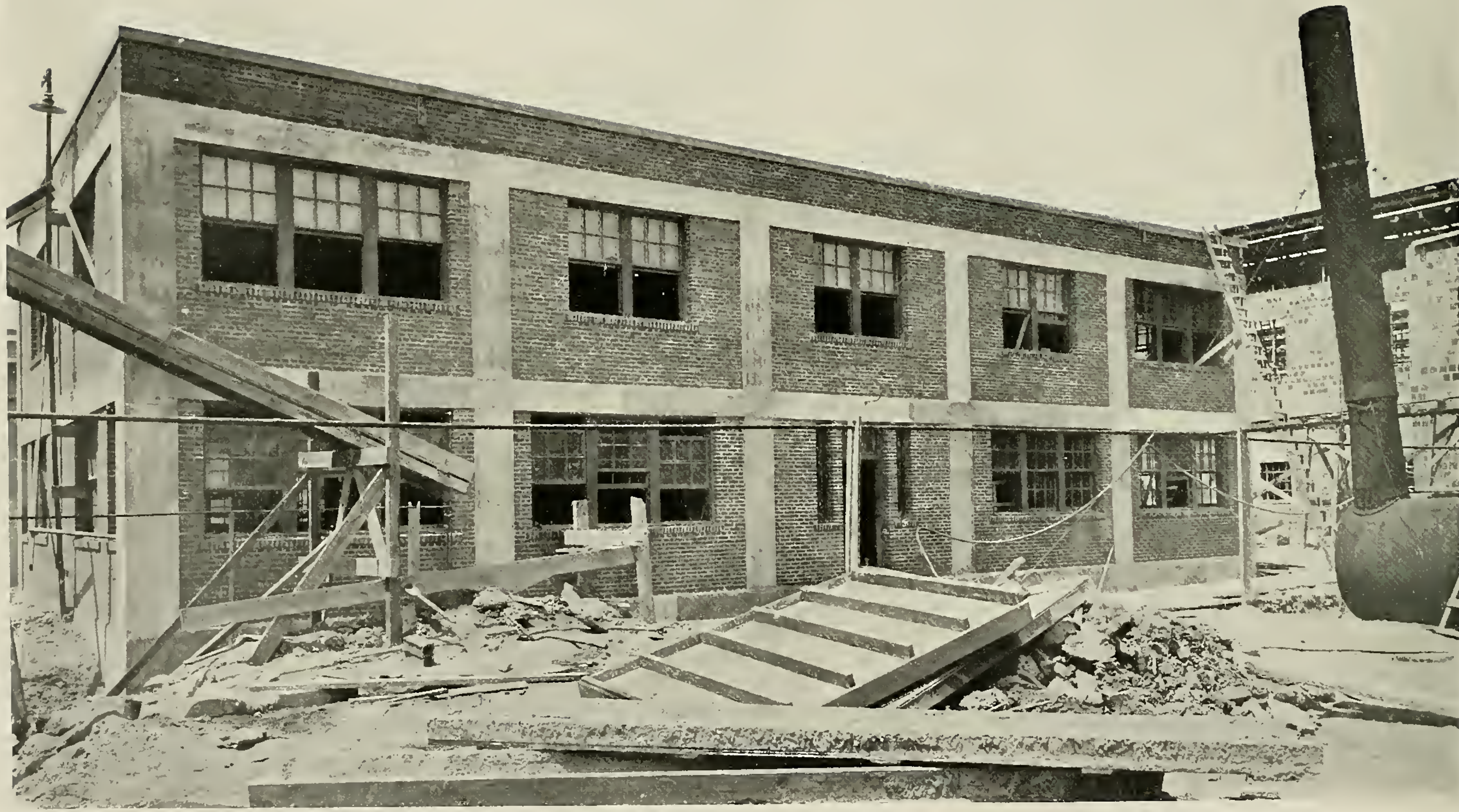
A view of Air Conditioning Equipment and Crystalizing Rooms. There were five miles of crystalizing pans (if placed end to end) in these rooms. Ammonium Nitrate Plant, Perryville, Md.



Air Conditioning Equipment. Ammonium Nitrate Plant, Perryville, Md.



Interior of Air Conditioning Building, Ammonium Nitrate Plant, Perryville, Md.



Nearly completed Laboratory, where 90 to 100 chemists made analyses every 15 minutes. Ammonium Nitrate Plant, Perryville, Md.

Abundance of fresh water, good railroad facilities and proximity to shell loading plants, which would use the product determined the selection a few days later of a site for the plant at the mouth of the Susquehanna River, at Perryville, Md. The location chosen was a farm of more than 500 acres.

A steam shovel started work on a railroad siding into the property on March 3rd, and construction of bunk houses, commissaries and temporary offices was begun. Frost was then leaving the ground and the wet clay soil was so heavy that it was not unusual to see four to six horses dragging a few railroad ties or a 30-foot steel rail. Even then the horses were mired frequently.

While this preliminary work was in progress corps of engineers and draftsmen were working night and day to prepare preliminary plans for the operating buildings. As soon as any apparatus was decided upon, it was ordered, and in spite of chemical equipment of all kinds, remarkably quick deliveries were secured.

A Plant Which Made Artificial Weather

When it is considered that a 10,000 horse-power power house, and installation of filters, the largest in the world, and the largest air conditioning installation in the world had to be designed and built, one can realize the tremendous job ahead. But about the middle of March sufficient detail of buildings had been developed so that the plans could be forwarded to the construction forces at Perryville and work started on the foundations.

Work on the power-house was started on April 30, and steam was developed in the first battery of boilers on June 19. The entire building was completed in sixty-one working days.

On May 25th, 10,000,000 pounds of raw material had been loaded into the store-houses. On July 3, the manufacture of Ammonium Nitrate was started and on July 8th the first product was obtained. The amount was small, due to the fact that all construction work had not been completed. The production quickly reached the capacity of 300 tons a day. And thus had the seemingly impossible been achieved. In a plant which did not exist ninety days previously and by the adoption of methods hitherto unknown and which were thought impractical for conditions in this country, a daily production of 600,000 pounds of ammonium nitrate was obtained, or 18,000,000 pounds per month.

The inflammable nature of ammonium nitrate made fire-proof construction necessary. And the size of equipment necessitated large buildings. Sixteen cast-iron pots—the largest ever cast, with bottoms integral with the sides—were used in handling the solution. These pots weigh 22 tons (49,280 pounds) each. More than five and one-half miles of crystallizing pans were installed in the crystallizing buildings. These would make a pan four feet wide, extending from the Battery to Central Park, New York.

To provide the 30,000,000 gallons of water used by the plant every twenty-four hours, the largest centrifugal pumps in the world were installed, connected with two 30-inch mains. The "artificial weather" was regulated largely with the use of these 30,000,000 gallons of water, the methods of control being such that outdoor temperature of 102 degrees or a minimum of below zero would not interfere with the maximum daily production.

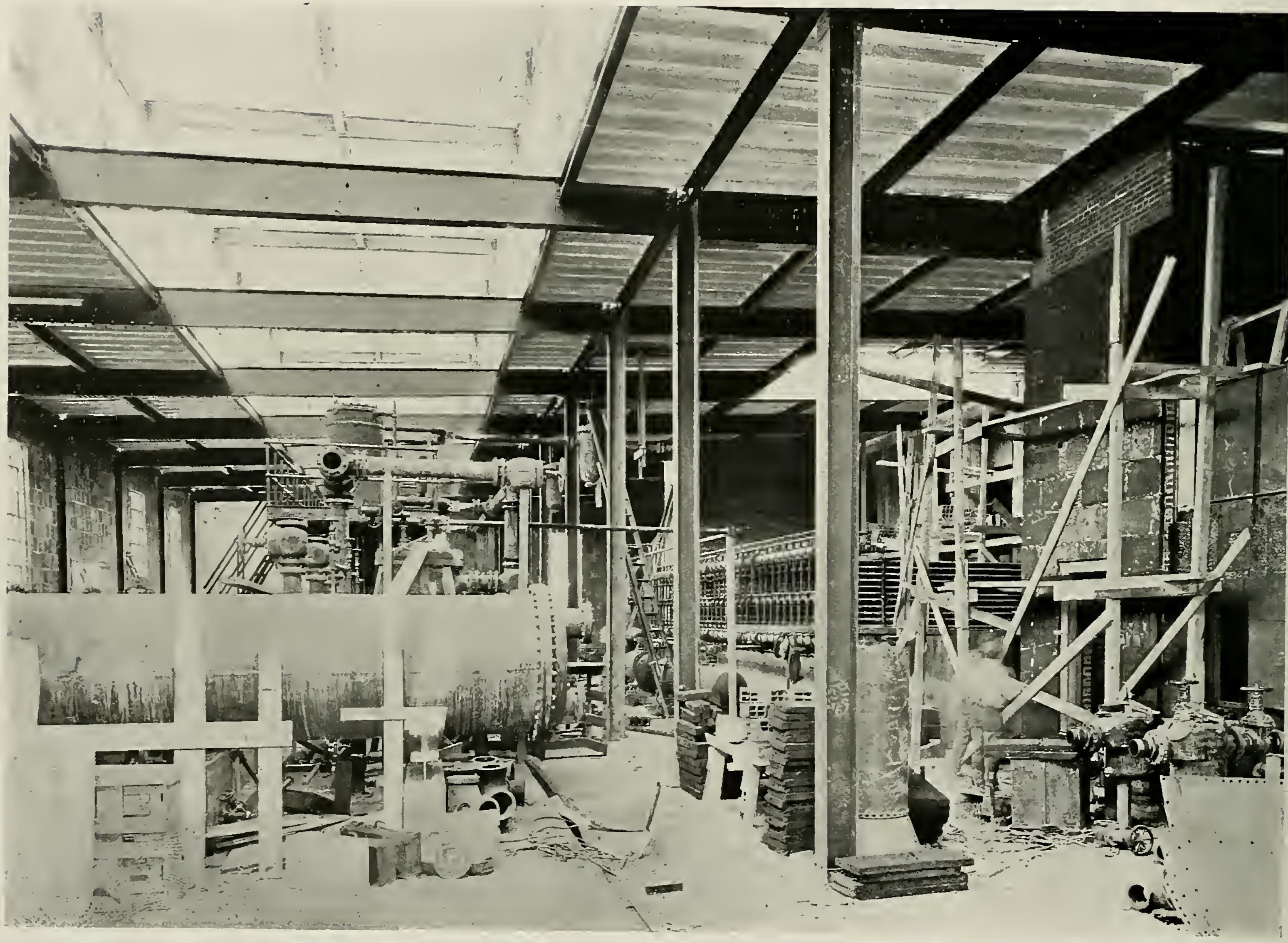
When the plant was started there were practically no housing facilities for employees. It was necessary to build a village adjacent to the plant. Three hundred houses, with five to seven rooms each, were constructed, equipped with modern plumbing and heating systems and supplied with filtered water, the quality of which is under such accurate control of the laboratories that the bacterial count was reduced from 2,000 per cubic centimeter to 50 per cubic centimeter. Besides the dwelling places, there were two stores, six boarding-houses, twenty permanent bunk houses, community kitchen building, school-house and community club-house. Ample protection against fire also was provided. The houses were rented to employees at a very nominal charge.

Sixty-five hundred men were employed in the construction of the plant and were housed in the most modern of dormitories and bunk houses. Eighty-five bunk houses were constructed, one being completed in five and one-half hours. The average cost per square foot was 65 cents, the lowest price of any in the country.

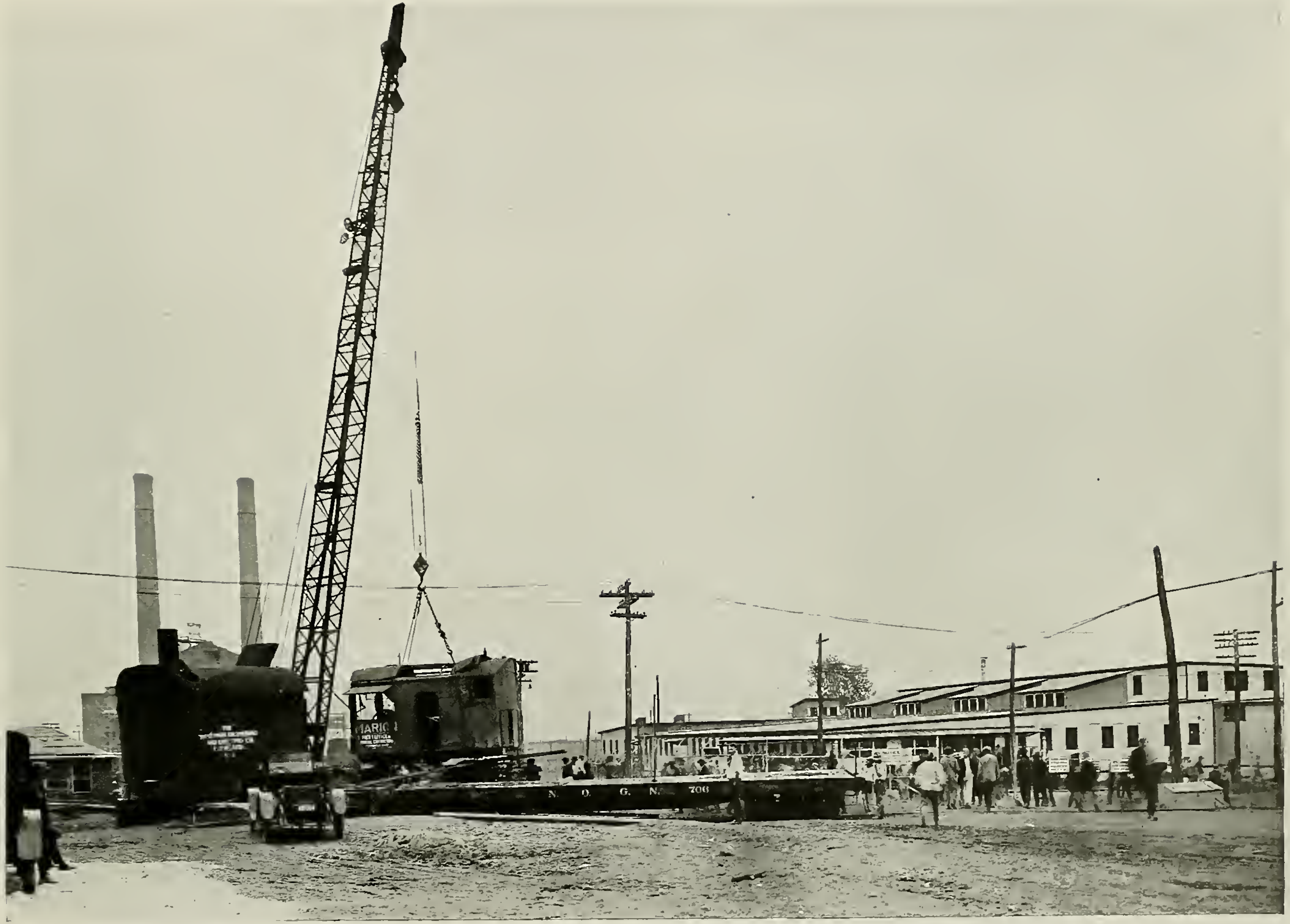
The total number of paid meals served in the modern commissary that was provided, from March 15 to July 31, was 861,454.

In order to appreciate the magnitude of the Perryville operation, a few figures are given here showing size of site, length of railroad tracks, roads, tunnels, materials used in the construction (exclusive of the village) etc.

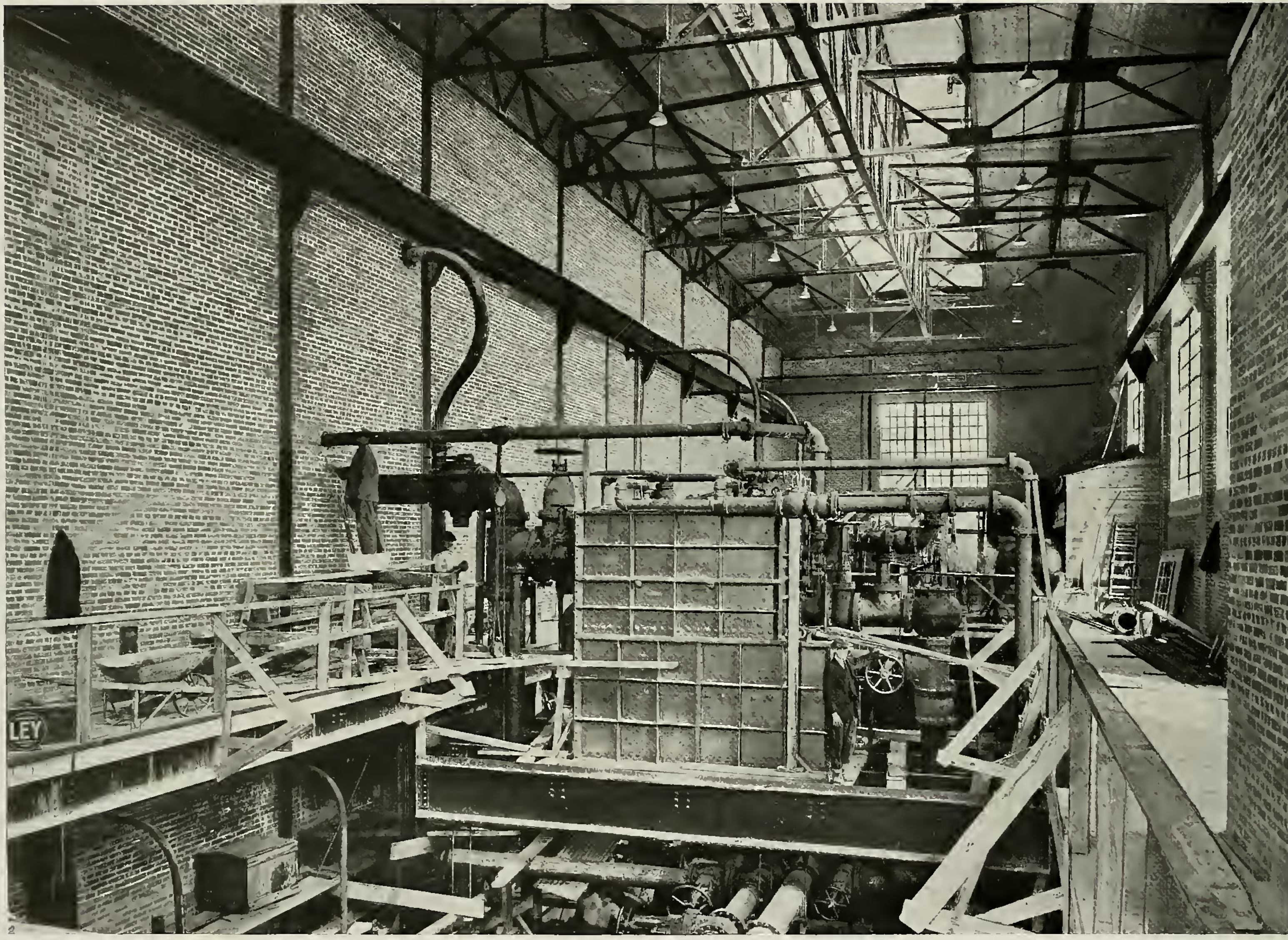
(Continued on page 53)



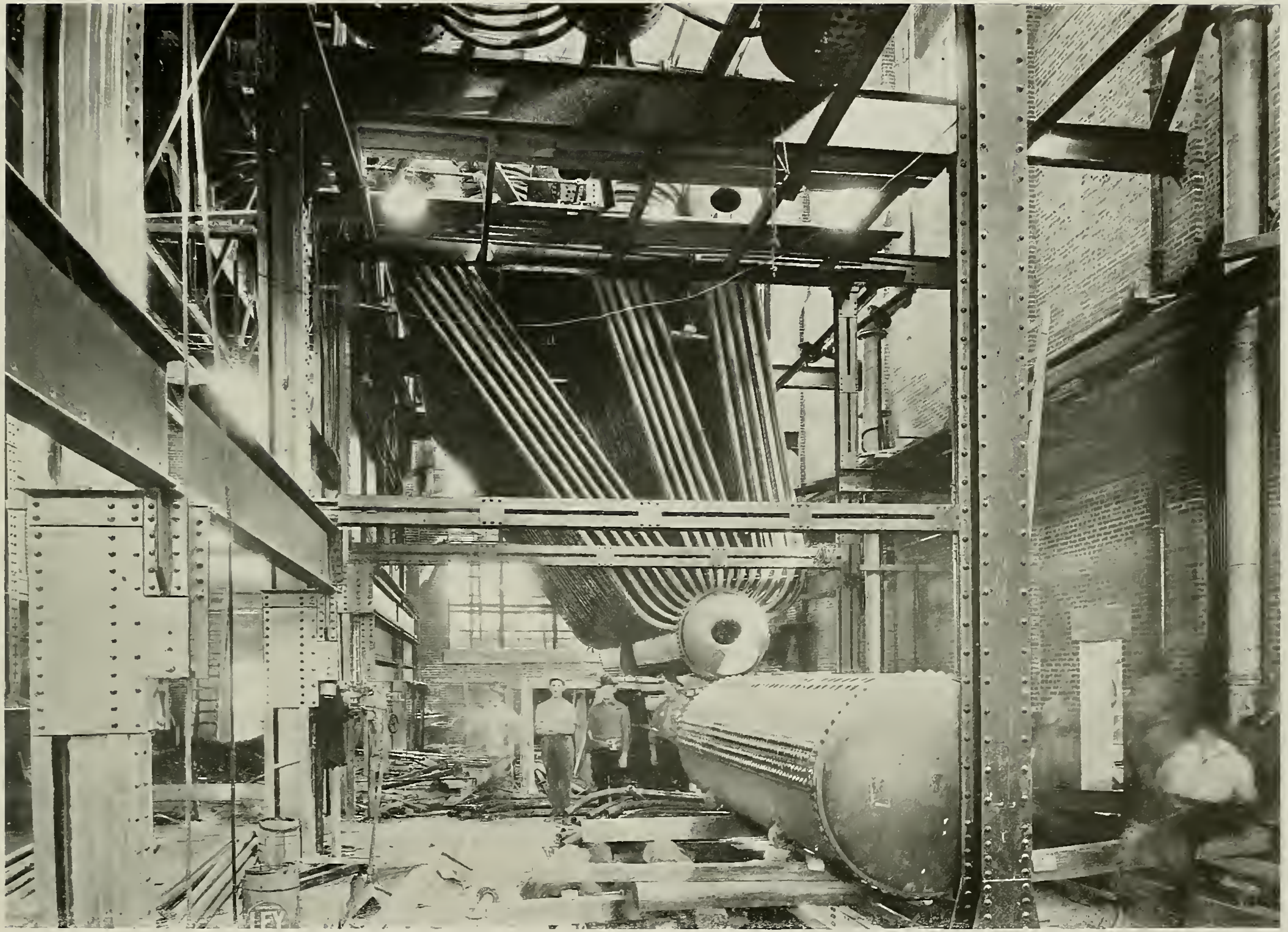
One of the partly completed Refrigerating and Air Conditioning Rooms. The air conditioning equipment is probably the largest in the United States. Ammonium Nitrate Plant, Perryville, Md.



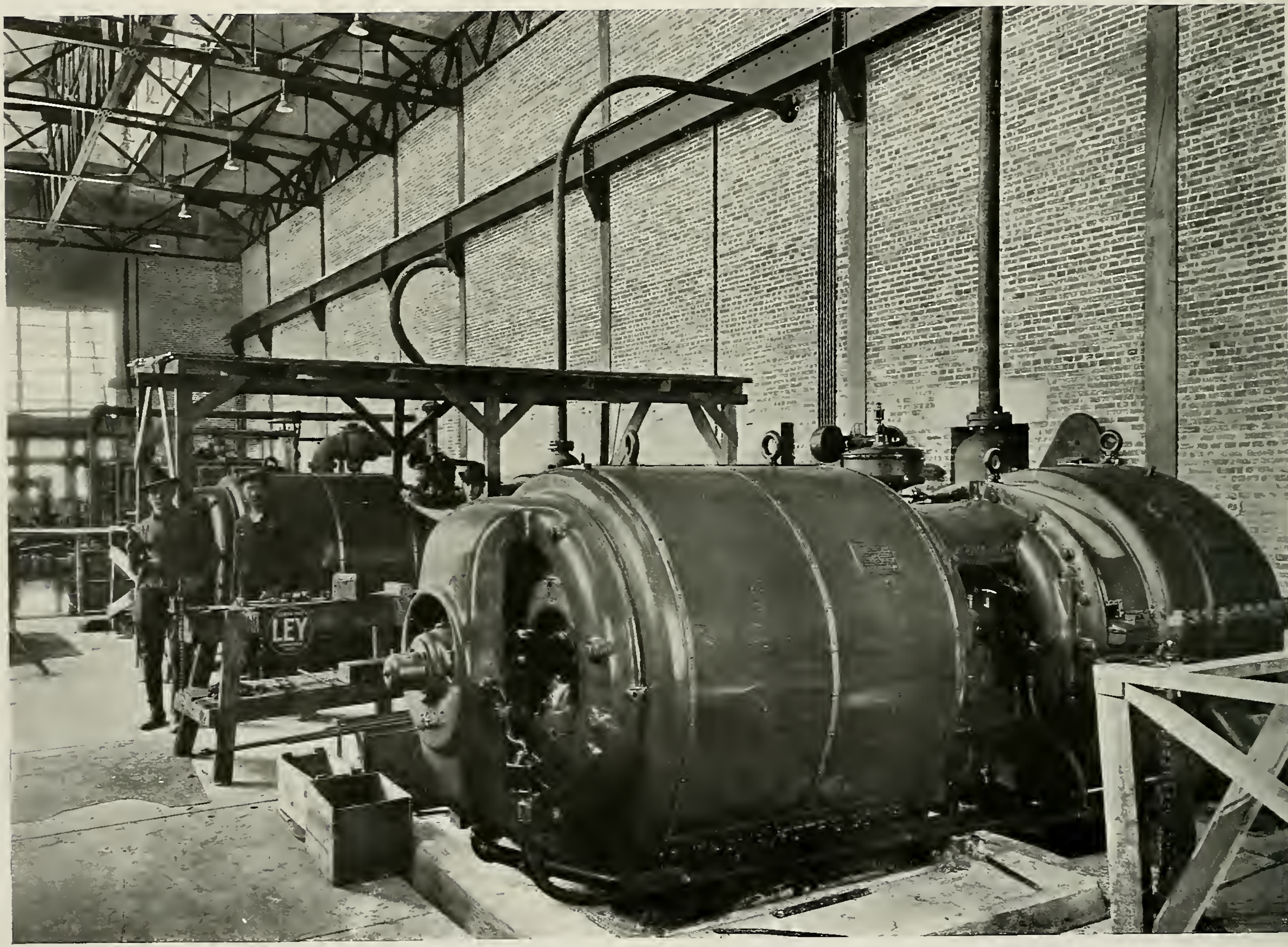
View of Commissary during construction. 14,000 meals were served daily. Ammonium Nitrate Plant, Perryville, Md.



Interior of Power House, with feed water heater under construction. Ammonium Nitrate Plant, Perryville, Md.



One of the 823 H. P. Boilers under construction. Ammonium Nitrate Plant. Perryville, Md.



Turbine Generators. 1,000 K. W. capacity each. Ammonium Nitrate Plant, Perryville, Md.

ATLAS POWDER COMPANY'S NITRATE OF AMMONIUM PLANT, PERRYVILLE, MD.

Description

Area of property	516 acres
Length	1¾ miles
Breadth	¾ miles
Area of plant site	35.8 acres

TRACK—PLANT

Miles of Track Laid

(a)	Standard gauge, permanent	6.36
	Standard gauge, temporary	1.32
(b)	Industrial gauge, temporary	1.42

Length and Size of Tunnels Outside Buildings

(a)	Steam tunnel	10′ wide x 8′	high	inside	1118′ 0″
(b)	Steam tunnel	5′ wide x 8′	high	inside	66′ 5″
(c)	Steam tunnel	5′ wide x 10′	high	inside	11′ 0″
(d)	Conveyor's tunnel	5′ wide x 6′ 6″	high	inside	242′ 5″
(e)	Conveyor's tunnel	5′ wide x 6′ 6″	high	inside	34′ 0″
(f)	Conveyor's tunnel	16′ wide x 6′ 6″	high	inside	20′ 0″
(g)	Water pipe	7′ wide x 3′ 6″	high	inside	185′ 0″

Number of Miles of Road Built and Miles of Pipe Laid for Both Water and Sewerage

Miles of Road

(a)	Village, permanent	2.273
(b)	Village, permanent	.70
(c)	Plant, permanent	.71
(d)	Plant, temporary	.40
	Fencing—plant and pump house	2.32

Water Supply

Plant and village, 20,000,000 gals. per day

Miles of Water Pipe

(a)	Village	3.00
(b)	Plant	3.06
(c)	Temporary	1.25

Miles of Sewers and Drains

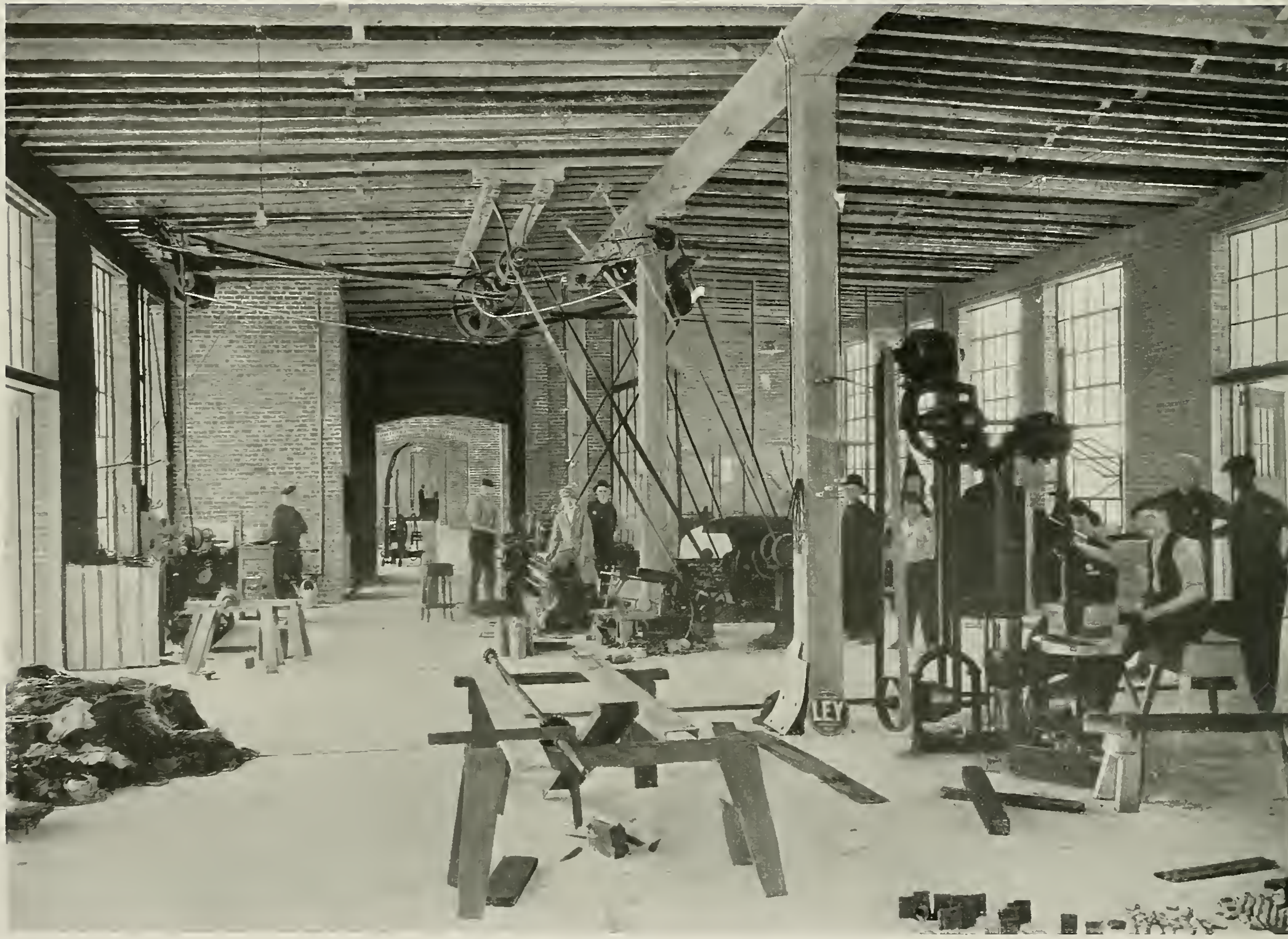
(a)	Village, main lines	3.51
(b)	Village, house connections	1.62
(c)	Plant	4.209

MATERIAL—PLANT

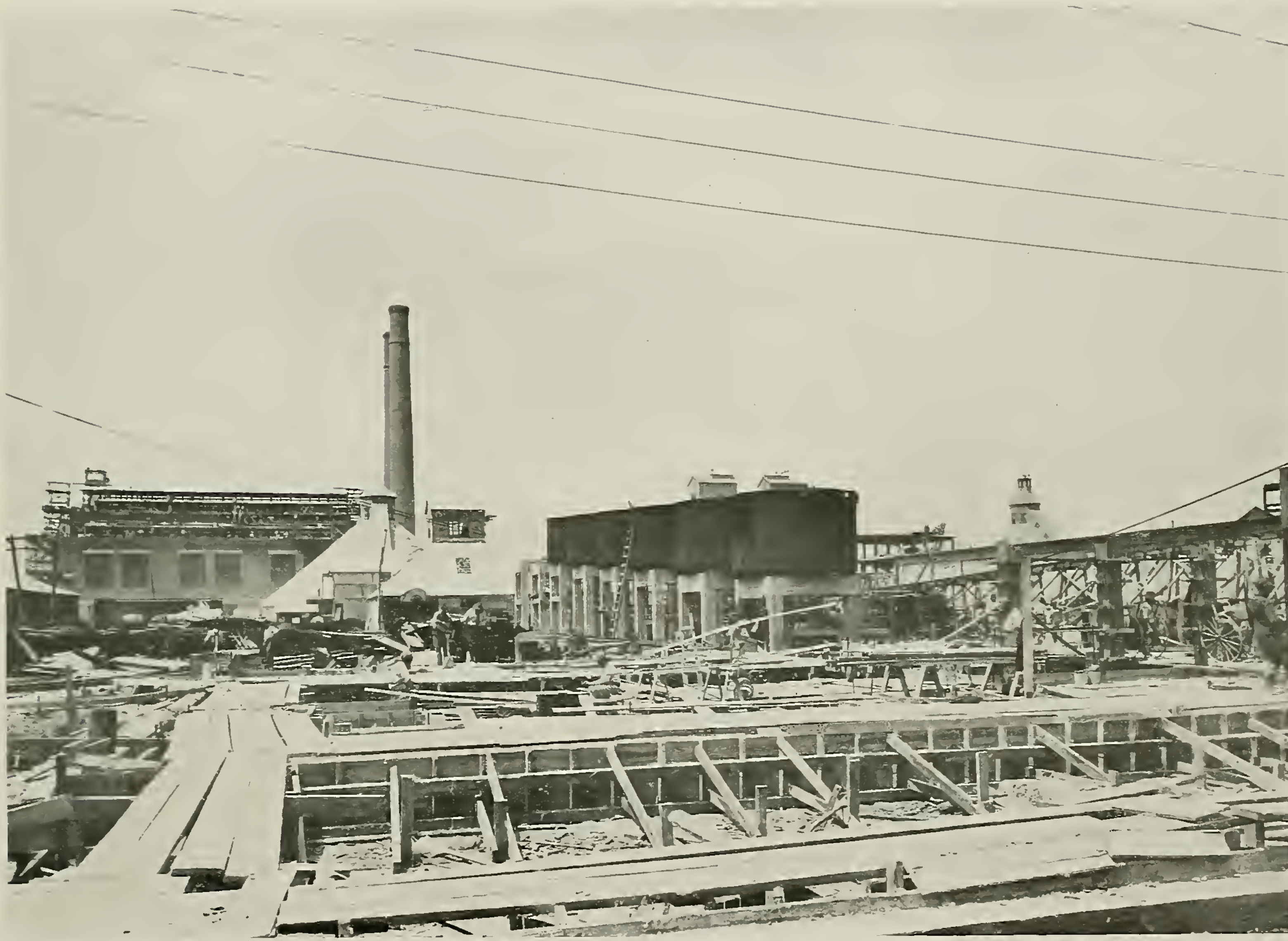
Note: This is an approximate estimate and does not include any allowance for breakage, wasteage or alterations

Excavation	40,159	cu. yards
Cement	52,483	barrels
Sand	21,108	tons
Stone	33,569	tons
Re-inforcing Steel	638	tons
Brick	2,356,000	M
Fire Brick	321,000	M
Paving Brick	93,400	M
Hollow Tile	770,388	sq. feet
Paving Tile	100,412	sq. feet
Structural Steel	3,920	tons
Steel Sash	42,912	sq. feet
B. M. Feet Lumber	754,952	B. M. feet
Lime	871	barrels
Cinders	6,198	cu. yards
Roofing	287,748	sq. feet
Concrete Walls and Piers	29,274	cu. yards
Concrete Floors	248,936	sq. feet
Forms	1,078,370	sq. feet

(Continued on page 59)



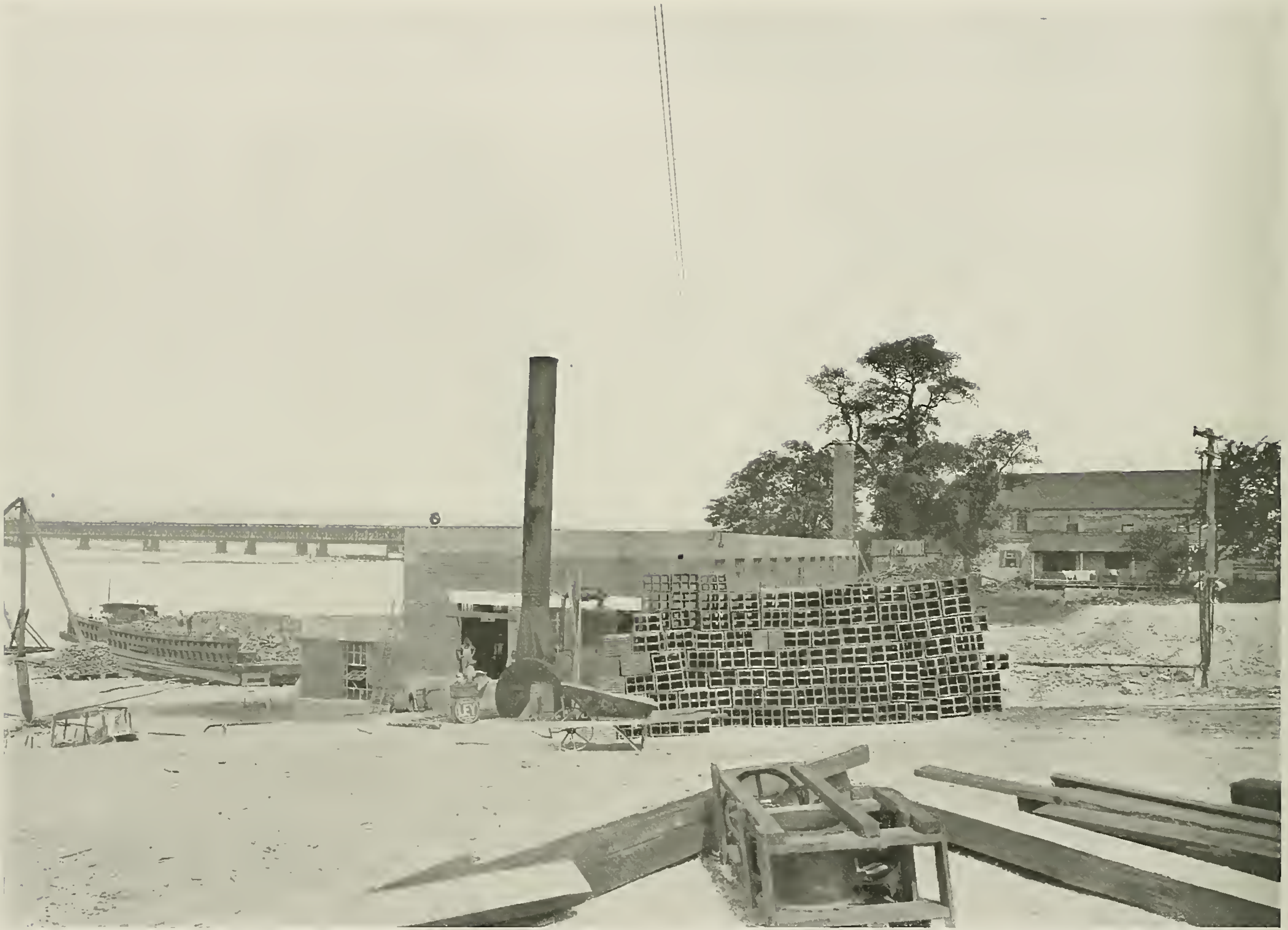
Interior of Machine Shop. Ammonium Nitrate Plant. Perryville, Md.



Cast Iron Digesters—the largest flat-bottom castings ever cast in this country. So large are these pots that the building was erected after the pots were installed. Ammonium Nitrate Plant, Perryville, Md.

View of Yard when plant was practically completed. Ammonium Nitrate Plant, Perryville, Md.

Dredge digging channel into intake for Pump House. This channel was dug out through the flat some 1,800 feet. It also shows rip-rap work at intake; also coffer-dam built to allow blasting of rock. Ammonium Nitrate Plant, Perryville, Md.



Pumping Station, nearly completed. This pump house has a capacity of 30,000,000 gallons per 24 hours. Ammonium Nitrate Plant, Perryville, Md.

Heating

Radiation in the plant, 15,000 sq. ft.; without the plant, 55,960 sq. ft. This is connected to power house through 3,300 feet of overhead and underground steam main.

All heating is from 200 horse-power steam mains, reduced to 100 and again to 3 and 5.

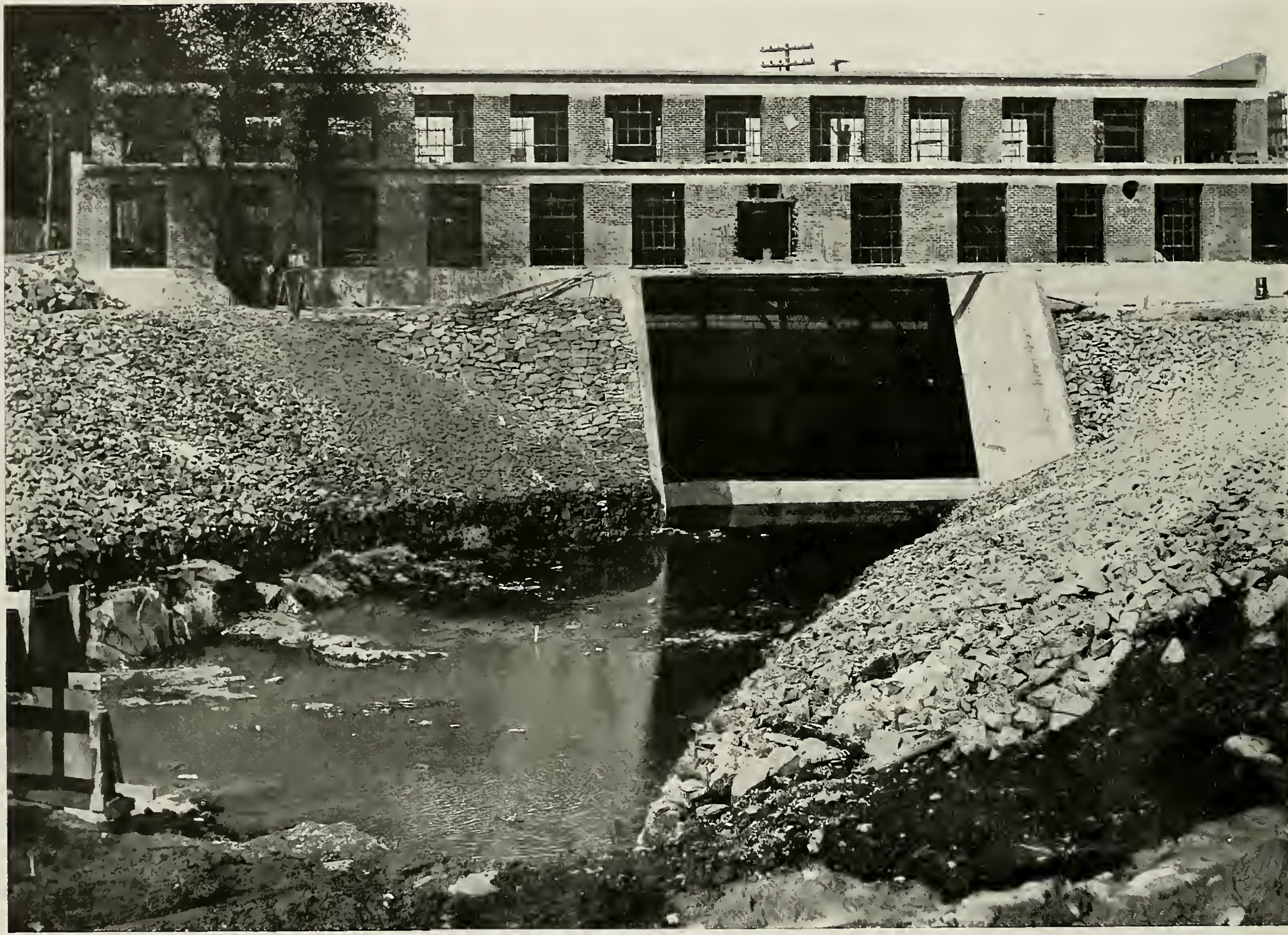
Steam Piping—There were used through the plant for steam purposes 256,500 feet of assorted pipe, from 20-inch down (48½ miles).

There were used in the power house 3,500 feet of fabricated pipe (Van Stone).

In addition to the acids and ammonium nitrate manufactured for war use, the Atlas Powder Company held contracts for other high explosives as follows:

Nitro-Cotton.
Fulminate of Mercury.
Trinitrotoluene (T. N. T.).
Tetranitromethylanilin (Tetryl).

The Perryville Nitrate of Ammonia plant remains a monument to American ingenuity and is but another demonstration that American resourcefulness overcame handicaps which at first seemed to be insurmountable.

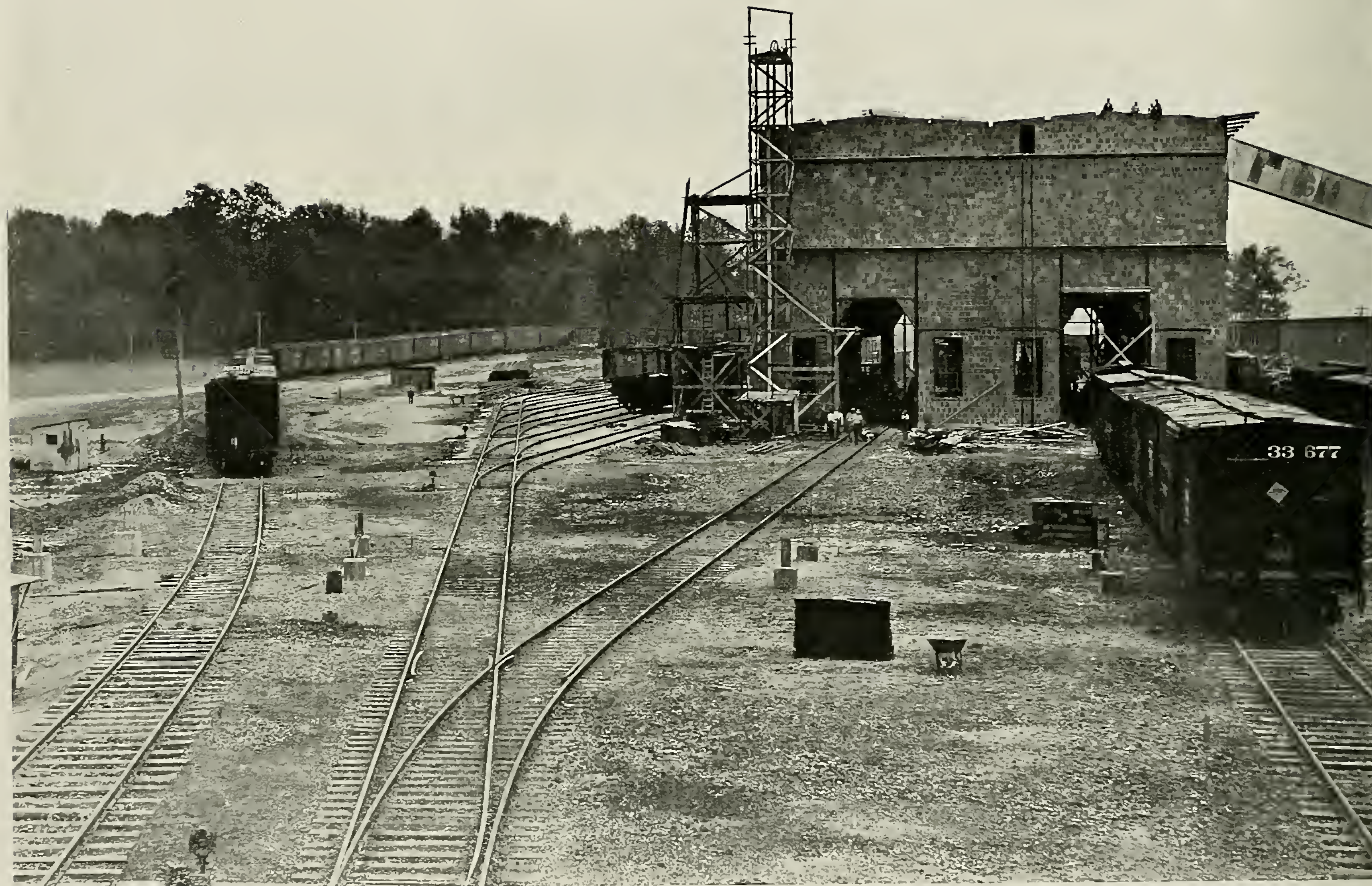


Pumping Station, nearly completed. Ammonium Nitrate Plant, Perryville, Md.

Pump House and Soda Store Houses. Capacity of soda storehouses, 45,000,000 pounds each. Power house rated capacity, 10,000 H. P.
Ammonium Nitrate Plant, Perryville, Md.

Plant about half completed. Ammonium Nitrate Plant, Perryville, Md.

Steel frame-work for the big Nitrate of Ammonium Storehouse. Ammonium Nitrate Plant, Perryville, Md.



Nearly completed Ammonium Nitrate Storehouse. In this building later was stored probably the greatest quantity of Ammonium Nitrate ever stored in bulk in one building—14,000,000 pounds. Ammonium Nitrate Plant, Perryville, Maryland.

The Bethlehem Loading Co., New Castle, Del.

Tetryl

THE manufacture of Tetryl by the Bethlehem Loading Company was begun in the latter part of 1915, because it was found to be impossible to purchase in the United States, Tetryl of a quality which would meet the requirements of their clients in connection with various contracts for complete rounds of ammunition.

Experiments were conducted in the New Castle plant of the Bethlehem Loading Company to ascertain the possibilities of making Tetryl which would pass the specifications of various European Governments calling for high melting points combined with severe stability and heat tests.

Laboratory results indicated that these desired results could be obtained, and it remained to be proved whether these results obtained in the manufacture of small quantities could be duplicated on a production basis running into several hundred pounds per day. Several attempts, which invariably resulted in explosions and fires, convinced Chemical Engineers that it was almost impossible under the then existing conditions, to obtain the necessary quality of equipment combined with the quality of labor necessary to produce Tetryl in economic quantities, without considerable risk to both plant and operators.

It was then decided to operate numerous small units with consequent multiplication of labor and equipment, involving greatly increased costs and with this procedure excellent results were obtained. a very high quality of tetryl produced, and a capacity of 25,000 pounds per month was reached in May, 1916.

At the time the U. S. Government entered the war, in April, 1917, the capacity of the New Castle Tetryl Plant was 25,000 pounds per month. This figure was limited merely by the requirements of the Bethlehem Steel Company, in connection with their complete rounds contract.

As soon as the Bethlehem Steel Company had fulfilled its obligations to the Allied Governments, it placed the New Castle plant at the disposal of the U. S. Government and in March, 1918, the entire plant was rented by the Ordnance Department, U. S. A., the Bethlehem Loading Company acting as their agent to operate the plant for the manufacture of tetryl.

The capacity, with practically no change in the plant, was increased to 50,000 pounds per month and eventually reached 100,000 pounds per month in September, 1918. During the months of September, October and November approximately 280,000 pounds of tetryl was accepted by the U. S. Government inspectors.

All the Tetryl supplied was of the same high quality as that supplied by the Bethlehem Company to their European clients and the best obtainable in the United States. Evidence of the entire satisfaction of the Government representatives with the material may be obtained from the fact that a very large order for additional Tetryl had been placed for manufacture in the New Castle plant just prior to the signing of the armistice. This order was, however, not proceeded with.

T. N. T.

Two immense T. N. T. plants were being constructed when the armistice was signed: these were at Giant, Cal., whose capacity was planned for 2,000,000 pounds per month, and Racine, Wis., the capacity of which was to be 4,000,000 pounds per month.

T. N. T. production records show, throughout the country, a total of 16,025,000 pounds per month; this from a monthly production of approximately 1,000,000 pounds when we entered the conflict.

Picric Acid

Contracts were placed for large quantities of Picric Acid; at the time of the signing of the armistice some 250,000,000 pounds of it were on schedule among the following concerns: Butterworth-Judson Corporation, 72,000,000 pounds; E. M. Davis, 42,000,000 pounds: Goodrich-Lockhart, 10,000,000 pounds; Hooker Electric Chemical Company, 2,000,000 pounds; Lansing Chemical Company, 4,434,000 pounds; O'Brien Sun Dye Company, 4,000,000 pounds; Nitro Chemical Co., 6,900,000 pounds; Semet Solvay Co., 72,000,000 pounds; Union Dye and Chemical Co., 10,000,000 pounds; the Lloyd Company, 400,000 pounds; and the Aetna Explosives Co., 27,600,000 pounds.

Fulminate of Mercury

Fulminate of Mercury was produced by the Aetna Company at Kingston, N. Y.; the duPont Company, at their extensive plant at Pompton Lakes, N. J., and the Atlas Powder Company at their plant at Webster, Pa. (near Tamaqua).

The production of Fulminate of Mercury (used in detonating fuses, boosters and primers) was about 50,000 pounds per month, sufficient for the work in hand.

Ammonium Picrate

Explosive D

Ammonium Picrate is used as the bursting charge for armor piercing projectiles. It is produced by an ammonia process which makes it less sensitive than the parent compound and lessens thereby the probability of its being affected by metals with which it must come in contact. When the United States entered the war, production of Ammonium Picrate was 53,000 pounds per month; when armistice was signed, close to a million pounds per month was being produced in the United States.

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